NIC Project UKPNEN03 Deliverable D5

Interim Report on Business Models

May 2022

Optimise Prime

HITACHI Inspire the Next · Uber · Scottish & Southern Electricity Networks · centrica · Royal Mail · UK Power Networks

Table of acronyms & glossary

The acronyms and terms used throughout this document are clarified below.

Table 1 – Table of acronyms

Acronym	Full form
AC	Alternating Current
ASC	Available Supply Capacity
BMS	Building Management System
CAPEX	Capital Expenditure
CCS	Combined Charging System
CHP	Combined Heat and Power
CO_2e	Carbon Dioxide Equivalent
CP	Charge Point
CPO	Charge Point Operator
CPPA	Corporate Power Purchase Agreement
CSMS	Charge Station Management System
DC	Direct Current
DFES	Distribution Future Energy Scenarios
DNO	Distribution Network Operator
DSR	Demand-Side Response
DUoS	Distribution Use of System charge
EFA	Exploratory Factor Analysis
EV	Electric Vehicle
FAST	Firm Adoption of Sustainable Technologies
FSP	Full Submission Pro-forma (in reference to the project proposal)
FSO	Future System Operator
FTE	Full Time Equivalent
GB	Great Britain
ICE(V)	Internal Combustion Engine (Vehicle)
IRR	Investment Rate of Return
ISO	International Standards Organisation
IT	Information Technology
KMO	Kaiser-Meier-Olkin measure
kW	Kilowatt

Acronym	Full form
kWh	Kilowatt hour
LAN	Local Area Network
LSOA	Lower Layer Super Output Area
LV	Low Voltage
MIC	Maximum Import Capacity
MID	Metering Instrument Directive
MPAN	Meter Point Administration Number
MPR	Maximum Power Requirement
MWh	Megawatt hour
NIC	Network Innovation Competition
NPV	Net Present Value
O&M	Operations and Maintenance
OCPP	Open Charge Point Protocol
OPEX	Operating Expenses
OZEV	Office for Zero Emission Vehicles
PHV	Private Hire Vehicle
PPA	Power Purchase Agreement
PTU	Programme Time Unit
REGO	Renewable Energy Guarantees of Origin
RFID	Radio-Frequency Identification
SoC	State of Charge
SFS	Strategic Forecasting System
SLA	Service Level Agreement
SSEN	Scottish & Southern Electricity Networks
TCO	Total Cost of Ownership
TfL	Transport for London
ToU	Time of Use
UK	United Kingdom
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home
WACC	Weighted Average Cost of Capital
Wh	Watt Hour
WLTP	Worldwide Harmonised Light Vehicle Test Procedure
WS	Workstream

Table 2 – Glossary of terms

Term	Definition
Un-managed charging	Charging of an EV at the rate set by the connection until it reaches full charge or is disconnected.
Smart charging	Charging via a smart CP equipped with two-way communication, enabling charging habits to be adaptive.
Aggregator managed charging	Smart charging is controlled by an aggregator to meet their specific objectives.
Depot managed charging	Smart charging is controlled by/on behalf of the depot operator in to meet their specific objectives and adhere to connection agreement constraints.
Flexibility	The ability to respond dynamically to a signal provided by the DNO to increase or decrease the power exchanged with the network, compared to an initial planned behaviour.
Profiled connection	A connection agreement where the applicable maximum demand limit (in kVA) varies according to the time of day and the season, up to 48 half-hourly time slots per day, with adherence to the profile actively managed through behind-the-meter smart systems and monitored by the DNO.

Executive summary

Optimise Prime is a third-party industry-led electric vehicle (EV) innovation and demonstration project that brings together partners from leading technology, energy, transport and financing organisations, including Hitachi Vantara, UK Power Networks, Centrica, Royal Mail, Uber, Scottish & Southern Electricity Networks, Hitachi Europe and Novuna Vehicle Solutions (formerly Hitachi Capital Vehicle Solutions).

The project is gathering data from over 3,000 EVs driven for commercial purposes through three trials. Optimise Prime will also implement a range of technical and commercial solutions with the aim of accelerating the transition to EVs for commercial fleet operators, while helping GB's distribution networks plan and prepare for the mass adoption of EVs.

Through cross-industry collaboration and co-creation, the project aims to reduce the impact of EVs on distribution networks and ensure security of electricity supply while saving money for electricity customers, helping the UK meet its clean air and climate change objectives. The project consists of three trial workstreams (WS) – WS1, investigating the impact of commercial vehicles charging at Homes, WS2, monitoring and optimising commercial vehicles charging in depots and WS3, which uses private hire vehicle (PHV) journey data to model the impact of these vehicles on the distribution network. The trial period for WS3 began in August 2020, with WS1 and WS2 trials commencing on 1 July 2021. All trials are due to conclude in June 2022.

Optimise Prime's outcomes will include:

- Insight into the impact of the increasing number of commercial EVs being charged at domestic properties, and commercial solutions for managing home based charging
- A site planning tool and analysis of optimisation methodologies enabling an easier and more cost-effective transition to EVs for depot-based fleets
- A methodology for implementing profiled connections for EVs, implemented in coordination with network planning and active management tools
- Learnings regarding how useful and commercially attractive flexibility services from commercial EVs can be to DNOs, and how such services could be implemented
- A significant dataset and accompanying analysis on the charging behaviour of commercial vehicles

This report forms the fifth Optimise Prime deliverable, D5, an interim report detailing the preliminary economic and behavioural findings of the project. This report outlines high level options for business models supporting the EV transition, including details of economic and behavioural factors that impact these models and lessons learnt from the implementation of profiled connections at depots and the management of commercial loads at residential properties.

Some of the key lessons and challenges, which are discussed in more detail throughout this report, include:

Practical findings from EV fleet operation:

- There are a wide range of factors that fleet managers need to consider when transitioning to EVs. Careful planning is essential and must consider business needs, site constraints (both physical and electrical) and the management of changes to business processes. A comprehensive guide based on the experiences of the Optimise Prime partners can be found in Section 2

Economic findings from Total Cost of Ownership (TCO) analysis of the project's Home, Depot and Mixed fleets:

- At present, whether total cost of ownership (TCO) favours EV or ICE fleets varies considerably across and within the different use cases
- EV prices are the key determinant of whether EVs make purely economic sense for a fleet, but there are many other factors influencing the cost, including connection costs for depots
- There have been significant increases in both electricity, diesel and petrol prices during the project, and prices remain unpredictable. The impact of recent electricity price rises is especially noticeable in fleets using public charging.
- The Congestion Charging exemption for EVs plays a crucial role in the breakeven point between the ICE and EV TCO for Uber, and significantly impacts other fleets operating in London
- Operational emissions analysis shows the clear environmental benefit for PHV and fleet drivers to switch to an EV

Behavioural findings, based on over 2,500 survey results from drivers and fleet managers:

- After drivers have tried EVs, they feel more positively about the technology
- EVs can offer significant value for drivers as well as the environment, making the business case for transition even stronger – there were overwhelmingly positive attitudes towards EV performance
- Charging facilities play a key role in giving drivers the confidence that they can fulfil their daily work tasks
- Reliable public charging infrastructure is critical for the adoption of EVs among PHV drivers, and will become more important as traditional home-based fleets rely more on public charging
- PHV charging behaviour in London remains difficult to predict because EV charging locations and timings are based on opportunity rather than habit
- Financial and operational barriers to EV adoption exist for PHV drivers; however, positive attitudes suggest a willingness to adopt once concerns are addressed
- Cross-fleet analysis of the behavioural results has shown remarkable consistency of views across the different fleets
- Between the two survey rounds EV drivers have shown a growing concern with access to charging, whereas for non-EV drivers over the same time interval this concern has decreased
- Drivers who are not happy with their EV generally have broad concerns over a range of technical, organisational, economic, and environmental aspects – there is not a single area that needs to be improved to get them on board

Lessons learnt regarding profiled connections:

- Adequate EV load, in proportion to background load, is needed for a successful profiled connection. Controllable EV load needs to be greater than the variation in building load
- Determining an accurate profile is key to being able to adhere to the profile. Profiled connections may need to be refined as more data becomes available

- Fleets need to be mindful of their future electrification requirements and have full electrification in mind. DNOs will need to be flexible to review changes in requirements over time
- Contractual, operational and technical measures may be needed to operate profiled connections, but could make the product less attractive to customers

Lessons learnt regarding separation of commercial load at domestic premises:

- Automating the reimbursement of charge-at-home electricity is necessary for larger fleets
- Gaining the trust of drivers through clear communication is necessary for the successful implementation of reimbursement solutions
- There are limitations in what can be achieved through a commercial solution at present, because the driver first has to pay the bill and then be reimbursed
- Communicating the complexities of optimisation and engaging drivers can be challenging
- Reliable communications was the key technical issue faced during implementation
- Thanks to regular shift patterns during weekdays, plug-in rates could be accurately predicted with an estimated 95% accuracy. Weekends and holidays remain more challenging to predict due to irregular shift patterns

Insights from interviews with flexibility providers:

- High complexity and the level of automation required to bring down transactional cost make it likely that fleets will participate in the flexibility markets via intermediaries such as aggregators or Charge Point Operators (CPOs)
- The value of EV flexibility remains difficult to predict
- EV flexibility at public CPs was generally believed to be too complicated to deliver

This report covers the following:

- **Section 2** takes the form of an operating guide for fleets looking to electrify, highlighting lessons learnt by the project partners when adding EVs to their fleets
- **Section 3** presents economic findings, focused on analysis of the TCO for EVs for our trial fleets
- **Section 4** provides an overview of results from a series of behavioural studies carried out with fleets in the UK
- **Section 5** gives insights from the initial trials of profiled connections in WS2
- **Section 6** provides lessons learnt from the management of EV load at domestic premises in WS1
- **Section 7** includes insights regarding EV flexibility services from interviews with market participants.

This report should prove valuable to any DNO considering how to plan for the future growth of commercial EVs and when considering the implementation of more flexible connection methodologies.

Vehicle fleet operators planning to implement EV infrastructure will find the fleet operating guide and TCO analysis useful in planning their transition and may use outcomes from the behavioural analysis plan on how they engage drivers in the EV transition.

Table 3 shows the requirements of Deliverable D5, set out in the Project Direction, and where each item can be found within this report.

Table 3 – Deliverable D5 Requirements

Deliverable D5: Interim Report on Business Models	
Evidence item	Relevant section of the report
Interim report outlining:	
The preliminary economic and behavioural findings	Economic findings are presented in Section 3 and behavioural findings in Section □
High level options for commercial solutions/ business models	Section 2 presents an operational model for fleet electrification, this is backed by the economic TCO analysis in Section 3. Considerations for commercial solutions for specific services are also noted in sections 5, 6 and 7
Early learning on profiled connections	Early learnings from profiled connections are presented in Section 5
Approaches for separation of commercial EV loads at residential level	An analysis of the approach taken to separation of and payment for commercial EV loads can be found in Section 6

The project is continuing to build on the interim findings presented in this report and will create updated business models at the end of the project in deliverable D7.

Optimise Prime is committed to sharing the project’s outcomes as widely as possible. The project will continue to engage with a wide group of stakeholders throughout the fleet, PHV, technology and energy industries through a programme of events, reports, and the project website www.optimise-prime.com.

1 Background & purpose

This report, the fifth deliverable of the Network Innovation Competition (NIC) funded Optimise Prime project, details the interim learnings from the Optimise Prime business modelling activities. It covers a range of economic, behavioural and technical topics that contribute to the overall business case for the project's methods and for fleet electrification more broadly.

1.1 Introduction to Optimise Prime

Optimise Prime is an industry led EV innovation and demonstration project that brings together partners from leading technology, energy, transport and financing organisations, including Hitachi Vantara, UK Power Networks, Centrica, Royal Mail, Uber, Scottish & Southern Electricity Networks, Hitachi Europe and Novuna Vehicle Solutions. The role of each partner is described in Table 4.

Table 4 – Project Partners

Partner	Description	Project Role
HITACHI Inspire the Next	Hitachi is a leading global technology group committed to bringing about social innovation. Two Hitachi companies are project partners. Hitachi Vantara and Hitachi Europe.	Hitachi leads the project, providing overall project management, energy and fleet expertise and project IT platforms. Hitachi is also developing tools for the depot trial.
UK Power Networks	Electricity DNO covering three licensed distribution networks in South East England, the East of England and London. The three networks serve over eight point four million customers.	London Power Networks is the project's funding licensee. UK Power Networks provides networks expertise and is developing new connections methodologies and flexibility products.
Scottish & Southern Electricity Networks	The electricity DNO covering the north of the Central Belt of Scotland and Central Southern England.	Supporting experiments within the Central Southern England region, ensuring wider applicability of methods.
Royal Mail	Royal Mail provides postal delivery and courier services throughout the UK. It manages the largest vehicle fleet in the UK with over 48,000 vehicles based at 1,700 delivery offices.	Royal Mail is electrifying depots and operates EVs. Project tools will be tested in the depots and data from the vehicles will be captured.
Uber	Uber is the fastest growing PHV operator in the UK. Over 70,000 partner-drivers use the app in the UK, with the majority in and around London.	Uber is providing journey details from EV PHVs operating in London for the mixed trial.
centrica	Centrica is a UK based international energy and services company that supplies electricity, gas and related services to businesses and consumers.	The British Gas commercial vehicle fleet will participate in the trial. Centrica will also provide charging and aggregation solutions for the home trial.

Partner	Description	Project Role
Novuna Vehicle Solutions	Novuna Vehicle Solutions, formerly Hitachi Capital Vehicle Solutions, is one of the UK's 10 largest leasing companies, with a fleet of over 95,000 vehicles ranging from cars and vans to HGVs.	Novuna supports the project's behavioural research activities, provides insight to the fleet market and supported the testing of the project's charging solutions.

Since early 2022, data from the use of over 6,000 EVs driven for commercial purposes is now being gathered and analysed. The EVs are primarily based in London and the South East of England, although some in the home trial (WS1) are located throughout the UK. Optimise Prime is implementing a range of technical and commercial solutions with the aim of accelerating the transition to electric for commercial fleet operators while helping GB's distribution networks plan and prepare for the mass adoption of EVs. Through cross-industry collaboration and co-creation, the project is aiming to ensure security of energy supply while saving money for electricity customers, helping the UK meet its clean air and climate change objectives and transition to a net zero carbon economy.

Optimise Prime aims to be the first of its kind, paving the way to the development of cost-effective strategies to minimise the impact of commercial EVs on the distribution network. Commercial EVs are defined as vehicles used for business purposes, including the transport of passengers and goods. Compared to vehicles used for domestic purposes, commercial EVs will have a much greater impact on the electricity network because of higher mileage and therefore higher electricity demand. The additional impact of commercial depot based EVs results from two factors: co-location of multiple EVs at a single depot location, and higher energy demand per vehicle resulting from higher daily mileage and payloads. The latter is also a factor when commercial EVs are charged at domestic locations.

Two DNO groups (UK Power Networks and Scottish & Southern Electricity Networks) across four licence areas are involved in the project. The consortium includes two of the largest UK commercial fleets (Royal Mail and British Gas) and a major PHV operator (Uber). This scale allows the industry to test different approaches to reducing the impact of vehicle electrification on distribution networks, in advance of mass adoption throughout the 2020s. This will also help understand the impact of a wide range of variables, including different network constraints, typical mileage, traffic characteristics, location (urban, sub-urban, rural) and availability of public "top-up" charging on the feasibility of electrification of commercial vehicle fleets.

By studying this diversity, the learnings generated by the project will be applicable to the whole of GB. Optimise Prime will deliver invaluable insights by using data-driven forecasting tools designed to allow networks proactively to plan upgrades. In addition, this project will create a detailed understanding of the amount of flexibility that commercial EVs can provide to the network through smart charging. Finally, a site planning tool has been developed to allow customers to model the impact of fleet electrification on their connection requirements. The tool will show customers how smart charging could be used to charge their vehicles within existing connection limits. Where smart charging alone is not possible, the tool will provide the information necessary to request profiled connections (a new type of connection, providing a consumption connection capacity limit that varies throughout the day) from the DNO. Taken together, these form a set of innovative capabilities that allow for optimised utilisation of the network capacity, adopting a "flexibility first" approach and only reinforcing the network where no flexible alternative is suitable. This will result in cheaper costs for all customers, those connecting EV Charge Points (CPs), and all electricity bill payers.

Optimise Prime is seeking to answer three core questions, set in the project's Full Submission Pro-Forma (FSP), relating to the electrification of commercial fleets and PHVs:

1. How do we quantify and minimise the network impact of commercial EVs?

We will gain a comprehensive and quantified understanding of the demand that commercial EVs will place on the network, and the variation between fleet and vehicle types. We will achieve this through large-scale field trials where we will capture and analyse significant volumes of vehicle telematics and network data. This data will enable the creation and validation of practical models that can be used to better exploit existing network capacity, optimise investment and enable the electrification of fleets as quickly and cheaply as possible.

2. What is the value proposition for smart solutions for EV fleets and PHV operators?

We will gain an understanding of the opportunities that exist to reduce the load on the network through the better use of data, planning tools and smart charging. Additionally, we will consider and trial the business models that are necessary to enable these opportunities. We will achieve this by developing technical and market solutions, and then using them in field trials to gather robust evidence and assess their effectiveness.

3. What infrastructure (network, charging and IT) is needed to enable the EV transition?

We will understand how best to optimise the utilisation of infrastructure to reduce the load on the network. This will be achieved through the collection, analysis and modelling of depot-based, return-to-home fleet and PHV journey data.

Answering these questions will enable network operators to quantify savings which can be achieved through reinforcement deferral and avoidance while facilitating the transition to low carbon transport. The trial will also assess the journey data to understand the charging and associated IT infrastructure requirements and implications for depot and fleet managers to be able to operate a commercial EV fleet successfully.

1.2 Purpose and structure of this report

The purpose of this report is to share the interim learnings from the Business Modelling workstream of Optimise Prime. The business modelling workstream has two main functions:

1. To identify economic and behavioural factors that may affect the implementation of electric commercial vehicles, and subsequently demand on the electricity networks; and
2. To analyse the outcomes of the trials, with particular emphasis on determining how the project's methods may be operationally implemented by fleets and DNOs.

This report draws on a range of work completed in the Home (WS1), Depot (WS2) and Mixed (WS3) use cases, including trial outcomes and supporting activities such as behavioural survey and cost analysis. This deliverable is an interim report, aimed at presenting initial findings from early analysis that may be of interest to project stakeholders. Where possible, lessons learnt during the project have been incorporated into the fleet electrification guide in section 2, to enable their use by fleet operators. Throughout the remainder of the trials the project will compile a much richer dataset, allowing the results of all of the trial experiments to be reported in future deliverables.

1.3 Trials context

Optimise Prime has been designed to answer the core questions by carrying out three trials, each of which align with the fleets and charging methods of Optimise Prime's three fleet partners (Table 5), and two project methods (Table 6) – specific technical and commercial solutions – are being tested throughout the trials.

Table 5 – Optimise Prime trials

Trial Number	Name	Partner	Description
1	Home Charging	British Gas Maintenance[1]	A field study of charging behaviour and flexibility with a return to home fleet.
2	Depot Charging	Royal Mail Delivery	A field study of charging behaviour and flexibility with a depot-based fleet. Additionally, the testing of profiled connections.
3	Mixed Charging	Uber PHV operator	A study based on analysis of journey data from electric PHVs.

Table 6 – Optimise Prime methods

Method 1 Smart demand response for commercial EVs on domestic connections	Currently the additional peak demand would trigger reactive network reinforcement with the costs being entirely socialised as domestic and non-domestic use is blended together. In Optimise Prime we aim to separate the commercial loads to make them visible, testing demand response approaches with commercial EVs charging at domestic premises to identify and quantify the available charging flexibility.
Method 2 Depot energy optimisation and planning tools for profiled connections	Currently depots request a connection based on 'worst case' estimated peak demand, often triggering network reinforcement. The cost is part paid for by the connecting customer and part socialised across connected customers. In Optimise Prime we aim to design and test smart charging and energy optimisation 'behind the meter', at depots, to be able to conform to an agreed profiled connection. We are developing the tools and processes to calculate the optimal connection profile and infrastructure, for each site, to minimise the connection cost and/or capacity used. We will also test demand response approaches to identify and quantify the available charging flexibility from an optimal profile. The project will develop the commercial arrangements to enable the rollout of the method following the project.

1.3.1 Trials Objectives

The Optimise Prime trials are being conducted using a common framework that was introduced in Deliverable D1 and further developed into a series of experiments in Deliverable D2. In brief, each of the trials is broken down into a series of objectives, listed in Table 7. Based on the project's core questions, the table shows which of the objectives is relevant to each trial. Building on the trial activities, the business modelling work reported in this deliverable contributes to the completion of these objectives.

[1] British Gas is a subsidiary of project partner Centrica.

Table 7 – Objectives of the Optimise Prime trials

Objective	Home	Depot	Mixed
1. Create and validate models that predict the effects of electrification of commercial vehicles on the network to enable optimal investment	X	X	X
2. Assess the effects of profiled connections on fleet EV transition		X	
3. Assess smart electrification strategies	X	X	
4. Assess the ability of EV fleets to provide flexibility services to the DNO	X	X	X
5. Evaluate operational limitations to commercial fleet electrification	X	X	[2]

[2] Additional to the agreed FSP scope, but will be included if Uber are able to provide summaries of driver and/or passenger ratings in comparison with ICEV data without additional cost to the project

2 Fleet Electrification Guide and Operating Model

This section provides a ‘step-by-step’ guide for fleet operators/managers considering the electrification of their fleets, developing a business case and planning for rollout. The guide also presents learnings from Optimise Prime on the operational capacity and capabilities required to operate a fully electric fleet. It focuses on aspects related to infrastructure readiness and the considerations that should be taken into account while selecting, installing and operating the required hardware and software solutions to optimise charging.

Optimisation refers to the creation of a charge schedule to:

- Charge vehicles within the existing connection capacity (Available Supply Capacity – ASC), or enable adherence to a profile agreed under a profiled connection agreement, thus avoiding or reducing connection upgrade cost and waiting time for a connection upgrade; and/or
- Reduce the cost of charging, by charging when electricity is cheapest; and/or
- Allow load shifting to respond to flexibility markets to generate additional revenue.

Aspects related to vehicle selection and standard fleet operation are not discussed in detail; they are only considered as far as they may interact with the ability of the fleet to benefit from charging optimisation.

This section builds on lessons learnt discussed in Deliverable D3 and aims to signpost activities that should be considered early in the electrification journey to enable effective operation and optimisation. However, the exact sequence of activities may differ depending on the capacities of each organisation and the characteristics of its fleet.

The process shown in Figure 1 is generic, and most steps apply to depot-based fleets, as well as mixed and home-based fleets, unless otherwise indicated. Details of this process are described in more detail in the following sections.

2.1 High Level Feasibility

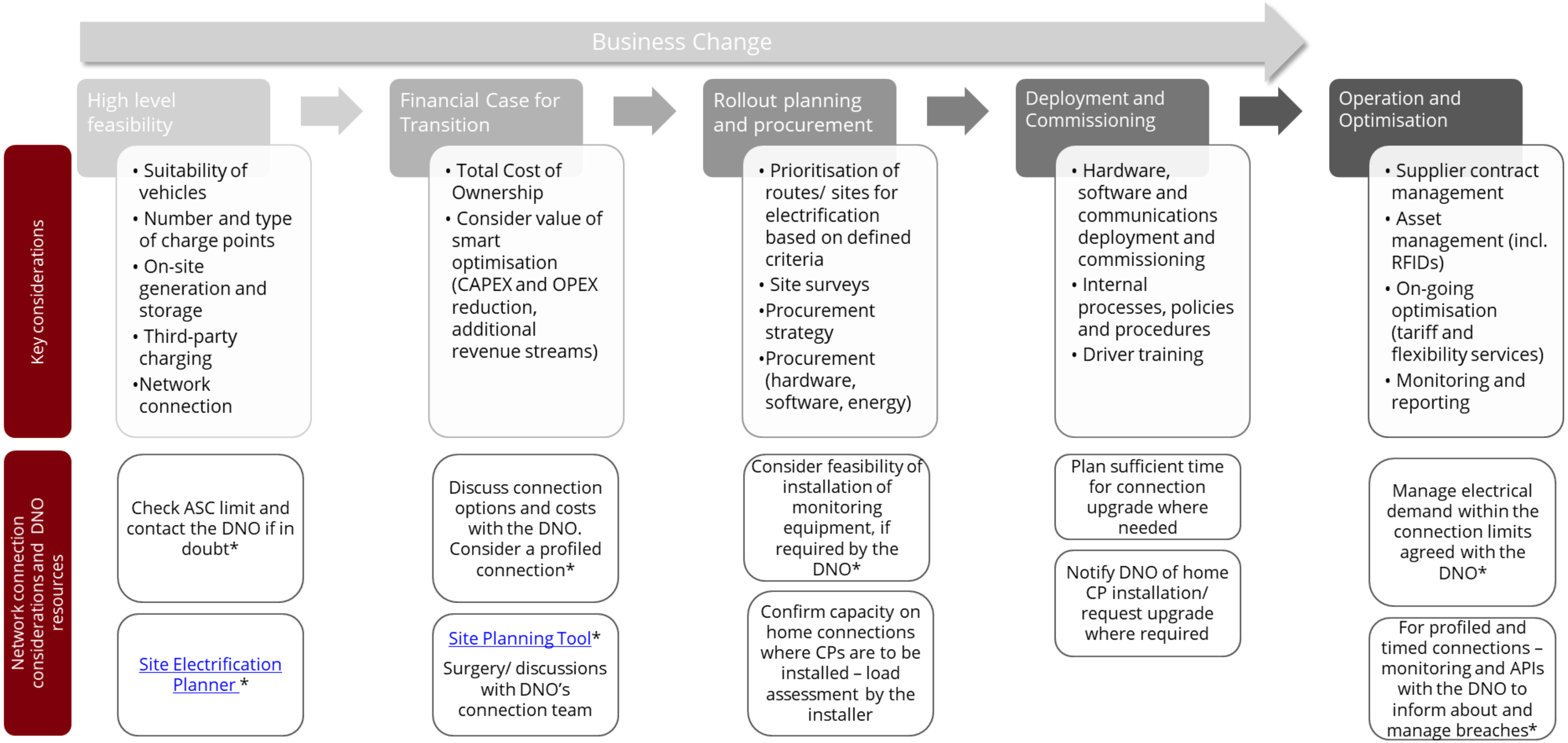
The objective of this phase is to understand the feasibility, costs and the likely timescales of the transition, and ensure that key constraints are well understood.

2.1.1 Vehicles

The first step to initiate fleet electrification is usually a feasibility assessment based on vehicle usage patterns and other operational requirements for example, to establish whether there are suitable EV models on the market to meet needs. The analysis of telematics data can be helpful to ensure that appropriate vehicles (e.g. battery size sufficient for daily/weekly distances) are available to address any concerns related to range and inform the prioritisation of transition, which could be phased by site or other grouping.

Fleet electrification in the Optimise Prime trials has generated several learnings with regard to EV procurement. For example, the initial EV models, chosen by Royal Mail, with a range of 80 miles and no Direct Current (DC) charging, while suitable under normal circumstances, proved problematic at times of peak service demand at depots with alternate-day charging (i.e. two EVs for one CP socket). Due to the inability to fast charge at public CPs, these vehicles may not be able to complete two consecutive shifts on the same charge. However, as new vehicle models come onto the market, with larger batteries, range becomes less of an issue.

Figure 1 – Fleet electrification process overview



* Relevant to depot-based fleets

In the early stages of EV rollout, Royal Mail prioritised electrifying shorter routes and Centrica prioritised drivers with off-street parking and sufficient space to install a charge point (CP), subsequently offering EVs to those who would need to rely on public charging. Analysis of telematics data, from the internal combustion engine (ICE) vehicles, will allow the fleet manager to estimate the electrical demand once the whole fleet is electrified, and therefore the future electrical requirements, total site capacity and numbers of CPs for a depot to meet future demand. Deliverable D4 Section 3.6 provides an example of how Royal Mail telematics data was used for this purpose.

2.1.2 CPs

The decision on the number and type of CPs will depend on the operational characteristics and requirements of the fleet, as well as the space availability and layout of the location. While the feasibility of the installation will need to be verified by site surveys, at a later stage, it is possible to estimate the number and type of CPs required based on operational requirements and telematics data. For example, for a depot-based fleet model, telematics analysis will uncover the appropriate times for charging that can meet the range requirements for the following shift (e.g. overnight, ready for the next day). This will help to determine the number and speed of the CPs required (see Appendix 9.1 for CP speed overview). Futureproofing CPs should also be considered – technology will progress over the lifetime of these assets (~10 years) and more vehicles will be able to benefit from a higher rate of charge. Where electrification is gradual, futureproofing cabling and network connection capacity upfront will also reduce the incremental cost of any additional infrastructure which might be needed in later stages.

Royal Mail opted for 7.4 kW single phase CPs, deemed to be sufficient for overnight charging. Initially, a one-to-one ratio of vehicles to sockets was the guiding principle to enable overnight charging without the need to unplug vehicles during that time. However, at some depots this was not possible due to space constraints and operational workarounds had to be implemented, such as charging every other day (and having staff swap EVs later in the evening). Based on learnings from the initial trials, Royal Mail has introduced a strategic target to reduce the CP to vehicle ratio to 1:2 across the fleet. This will require business processes to be put in place to manage alternate day charging. The process will be managed by the depot managers and is intended to be prescriptive, with charging schedules defining when and where each vehicle should be plugged in.

From the point of view of optimisation, having some flexibility in the times of charging is desirable, and a one-to-one CP to vehicle ratio with predicable plug-in patterns is easiest to manage. Faster, three phase 22 kW CPs also allow quicker charging and therefore more flexibility in times at which vehicles can be charged, so long as the vehicles are capable of charging at this speed. These benefits need to be weighed against additional infrastructure costs. For example, a three phase CP may be approximately 20% more expensive than a single phase CP, and require larger cabling, but it provides a future proof solution as more EVs start to accept an increasingly higher Alternating Current (AC) charging rate.

2.1.2.1 Home-based Fleet Considerations

For home-based fleets, the ability to install a home CP is a major consideration. Availability of off-street parking and space for CP installation is not the only barrier. Centrica found that in many residential properties, particularly in locations with no gas connection where electric storage heaters are often used, the domestic electrical installation is already at capacity or nearly overloaded.

In terms of process, Centrica perform the initial domestic load assessment and depending on location, the DNO may subsequently choose to perform a physical load assessment too. Centrica estimate that approximately 25% of potentially suitable locations are not able to proceed due to the result of the load assessment or due to services being looped. 'Looped services'[3], are where two properties share a single electricity service cable, can also lead to delays and increase the costs of installation. Such supplies may need to be 'un-looped' to enable CP installation, with potentially intrusive works.

Location of the parking space may also create issues for CP installation. For example, if it is located at the far end of a garden, a lengthy electrical cable will likely need installing or replacing, causing additional cost and disruption that not all drivers welcome.

Where home charging is not available, alternative solutions can be considered. For example, as part of the Virtual Fuel Card offering, Centrica has negotiated arrangements with public charging networks that give drivers, who do not have access to a driveway, an ability to charge conveniently, at reduced rates, billed directly to the company. As of November 2021, approximately 10% of Centrica's 800 EVs exclusively utilised public charging (and this is forecast to increase as more of the fleet converts). However, home charging is the default option, wherever possible, because of its convenience and the lower cost of charging on a domestic electricity tariff (when compared with a public CP).

The applicability of Office for Zero Emission Vehicles (OZEV) grants should also be considered. Currently grants apply to individual installations, thus the driver must be the owner of the CP installed at their home to be eligible. Without the OZEV grants, the CPs are likely to be fully funded by the employer and retention clauses can be considered for the drivers, obliging them to cover part of the cost should they leave the company before a specific period. However, due to lower charging costs on domestic tariffs as compared to public charging, Centrica is taking steps to make the CP installation as accessible to as many drivers as possible.

2.1.2.2 Future CP innovations: Vehicle to Grid (V2G)

Vehicle to Grid (V2G) CPs can make other services available, such as selling energy back to the grid, or discharging the vehicles to cover other demand on the site during times of high electricity prices to reduce the overall energy cost. While V2G is not in the scope of Optimise Prime, it may become an option in future years for fleets to create additional value from flexibility. Other innovation projects are exploring the value of V2G in in different contexts, for example: project Sciurus estimated that a domestic V2G CP could make the vehicle owner £410 per year compared to an unmanaged CP[4], a modelling study concluded that V2G could deliver 20% to 60% more value than smart charging, depending on the value streams targeted[5]. As part of the V2G Hub initiative UK Power Networks have helped develop a guide to the potential benefits to customers of V2G technologies which can be found at https://www.v2g-hub.com/services/. UK Power Networks is also working as part of the Powerloop[6] consortium to trial a new tariff with payments for V2G exports.

The price of V2G CPs remains a major barrier. However, as technology advances the premium (cost difference between a V2G and a smart CP) is expected to reduce from the current

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[3] UK Power Networks, Looped Services https://www.ukpowernetworks.co.uk/internet/en/help-and-advice/documents/looped_services.pdf [accessed on 16.02.2022]
[4] Commercial Viability of V2G: Project Sciurus White Paper, January 2021. Available at: https://www.cenex.co.uk/app/uploads/2021/01/V2G-Commercial-Viability-1.pdf [accessed on 27.09.2021]
[5] Cenex, Understanding the True Value of V2G. 07.05.2019. Available at: https://esc-non-prod.s3.eu-west-2.amazonaws.com/2019/06/Cenex-WP-2-True-Value-of-V2G-Report.pdf [accessed on 27.09.2021]
[6] Powerloop website https://octopusev.com/powerloop

~£4,000 to between £660 and £1,164 in 2030[7]. To date, the choice of V2G capable vehicles has also been limited, as V2G capability via DC charging currently relies on the CHAdeMO protocol, primarily limited to vehicles produced by the Nissan-Mitsubishi alliance. The Combined Charging System (CCS), the most common DC charging protocol on the market, does not currently enable V2G, although the body promoting CCS, CharIN, has a roadmap for implementing Vehicle to Home (V2H) and then V2G into the CCS standard by 2025[8]. Once the standard becomes available, it will likely take some time for compatible vehicles to come onto the market. Meanwhile, a number of vehicle manufacturers such as Hyundai and VW are investigating the potential for V2H and V2G via AC charging. While V2G potentially offers financial benefits, the use of this technology must be balanced against the requirements for operational use of the vehicle – for example, a vehicle providing an 'on call' response service may not be a suitable candidate for V2G.

2.1.3 On-site generation and static battery storage

The option to install LCTs may be considered on suitable sites with sufficient space for on-site electricity generation such as solar PV and wind power. Analysis of site electricity demand should be conducted to establish how generation and/or energy storage could contribute to lowering energy costs and the achievement of carbon emission reduction targets. At this stage initial estimates can be sought from installers to understand the cost and generation potential.

Requirement for on-site generation and storage might have an impact (either positive or negative) on the network connection requirements and costs, so it is important to discuss these options with the DNO while considering the changes in the connection agreement. In cases of depots connected to a constrained part of the electricity network, on-site generation and energy storage may deliver significant benefits by allowing the accommodation of more CPs within a lower ASC and reducing the Capital Expenditure (CAPEX) on electrical infrastructure. The ASC is the maximum amount of power a site can import from the network at any given point in time. It is measured in kiloVolt-Amps (kVA). It may also be referred to as Maximum Import Capacity (MIC) or Maximum Power Requirement (MPR). The ASC is first agreed with the DNO at the time of connection and may be varied after that.

2.1.4 Third-party charging

To maximise the utilisation of the charging infrastructure, and improve the economics of the electric fleet, some fleet operators may wish to consider granting access to their charging infrastructure to third parties at times of low utilisation by their own fleet. In doing this, businesses need to be mindful of the potential safety and security issues resulting from allowing members of the public into busy operational depots.

Where sufficient electrical connection and space for additional charging infrastructure is available that can be separated from the main operations and dedicated purely to third-party charging, these can be monetised through an agreement with a third-party charging operator.

To make third-party charging economically viable, the benefits of improved utilisation/ additional revenue will need to outweigh the cost of managing site access and operations (including booking and billing) and the potential limitations on optimisation, as third-party charging is typically less predictable.

[7] Element Energy, V2GB - Vehicle to Grid Britain final project report. Available at: http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/06/V2GB-Public-Report.pdf [accessed on 27.09.2021]
[8] https://electricnation.org.uk/2020/09/02/the-future-of-vehicle-to-grid-ev-charging/

2.1.5 Network connection – depot-based fleets

For depot-based fleets, it is important to check the depot's ASC early in the process. Some depots will have sufficient capacity, however if the ASC is insufficient to accommodate the envisaged number of CPs in addition to the baseload demand of the building, and the depot is in a constrained part of the electricity network then a network upgrade may be required. The costs of network reinforcements might have a material impact on the total cost of fleet electrification, however smart charging can significantly reduce this impact.

The current ASC of a site can be found in the connection agreement (this is an agreement between the site owner and the DNO). If this is not available, the capacity in kVA on the electricity bill paid by the site can serve as a guideline. Smaller sites without a specific ASC will be limited to 23kVA (single phase) or 69kVA (three phase).

The next step involves comparing the maximum demand, i.e. the most the site could draw from the distribution network, to the site's ASC. This is the sum of the peak site demand and the maximum demand (i.e. total power from all proposed CPs) from the planned charging infrastructure[9].

- If the maximum demand is within the ASC and total CP demand is less than 30% of the total site demand, then the DNO only needs to be notified within 30 days of installation.
- If EV charging takes the maximum demand above the ASC or total CP demand is more than 30% of the total site demand then a connection upgrade might be required and the installation must be agreed with the DNO, where alternative mitigations may be discussed.

The effect of maximum demand on the network can be reduced by applying smart charging and the cost of increasing the ASC can be clarified with the DNO on this basis. To ensure network integrity, the DNO may also require an import/export limiting device, which would be approved by the DNO as an automatic way to curtail excessive load. Such arrangements are novel and their application to low voltage connections are being developed as part of Optimise Prime. Section 5 describes how such an arrangement could be implemented.

Types of connections currently available and being trialled include:

- **Firm connections** – traditionally, a DNO would offer a 'firm' connection, meaning the same ASC level is applicable throughout the day, which cannot be exceeded.
- **Flexible connections** – alternative connection type currently used mainly for renewable generators. A curtailment assessment report gives an estimate of how often the renewable generator's connection may be curtailed over the course of one year. This estimate depends on factors such as historical network power flows, typical load and generation profiles. Curtailment is managed by the DNO based on available network capacity. Flexible connections allow generators to connect to the network faster and at a lower cost. This connection type is less well suited to demand customers, such as EV fleets, where operational reliability is important.
- **Timed connections** – alternative connection type currently applied in UK Power Networks' areas to a small number of customers connected at high voltage level, such as bus depots. Such connections specify different ASC levels at different times of the day, with up to four different time bands. In order to maintain network integrity, as a last resort measure, the DNO may disconnect a sacrificial load at the site if the agreed ASC is exceeded, following a series of warnings issued to the operator. This connection type

[9] Engineering Standard EDS08-5050 includes some diversity factors that may be helpful here: https://www.ukpowernetworks.co.uk/-/media/files/electric-vehicle-charging/eds-08-5050-electric-vehicle-connections.ashx

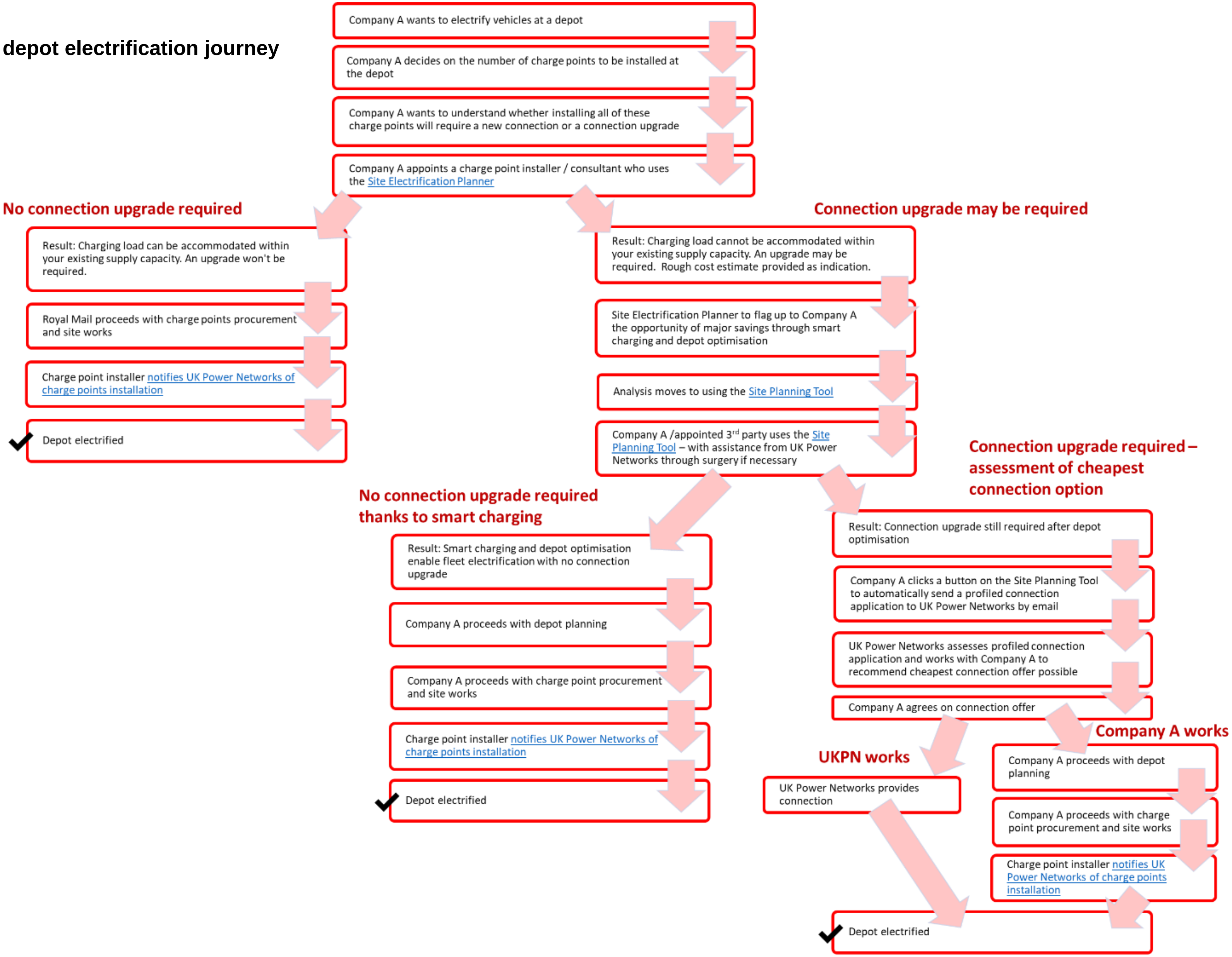
became available in 2020 and five bus garages have so far benefited from a timed connection, each saving between £100,000 and £900,000 on connection costs when compared to a firm connection. The monitoring solution has shown that compliance with the profile at each site has been successful thanks to reliable load management systems used by bus garages, and it has not been necessary to revisit the connection agreements.

- **Profiled connections** – a new connection type being developed and trialled by Optimise Prime. The concept is similar to the timed connection, but profiled connections are extended to customers connected to the low voltage (LV) network, and can be more granular (e.g. allowing up to 48 different half-hourly ASC limits throughout the day). The design of profiled connections is intended to offer the customer a connection profile best matched to their needs while ensuring a high level of utilisation of network assets and reducing the overall cost to customers.

With smart charging, a LV-connected depot operator might be able to reliably reduce their peak demand and apply for a lower firm connection or, in the future, for a profiled connection.

Figure 2 shows an example of a depot electrification journey, with focus on the interaction with the DNO and references to the tools available to support the depot operator and the appointed installer in this process. The exact sequence of these steps may differ, depending on the amount of data available, types of analysis conducted at earlier stages of feasibility, and the specifics of the procurement process.

Figure 2 – Example depot electrification journey



Optimise Prime has developed two self-service tools to support this process:

- **Site Electrification Planner:** https://www.optimise-prime.com/site-planner designed to give a quick estimate of the cost to connect EV CPs at existing sites based on four inputs (number of CPs planned, power rating of the CPs, the ASC and current peak demand).
- **Site Planning Tool:** https://www.optimise-prime.com/site-planning-tool which requires more granular inputs and calculates the ASC required under different optimisation scenarios including a base case, unmanaged charging and smart charging. The results from the tool will provide a good basis for discussion with the DNO.

UK Power Networks also have a lot of resources available on their website to help with EV CPs connections, including guides. They have also created a short overview of the process available here: https://www.ukpowernetworks.co.uk/-/media/files/projects/connections-guides/the_connection_process-over-70kva.ashx

Most DNOs hold 'connection surgeries' with their connections team free of charge (e.g. UK Power Networks & SSEN), where the different options can be discussed before a connection application is made.

A fleet operator can find their local DNO at the following link: https://www.energynetworks.org/operating-the-networks/whos-my-network-operator.

2.1.6 Network connection – home based fleets

Installation of a home CP on domestic connection at an employee's home will not usually lead to additional connection costs. However, as mentioned above, in some cases the connection may already be overloaded and an upgrade to a three phase connection may be required to accommodate a CP. UK Power Networks' innovative Smart Connect tool can automatically assess requests for connection of EV CPs and other LCTs, offering instant approval when within existing capacity or automatically referring to the relevant team if additional works are needed.

Further detail on the upgrade which may be required is available here https://www.ukpowernetworks.co.uk/electricity/upgrade-reduce-electricity. The cost of upgrading to a three phase solution in UK Power Network's area normally ranges from £1,700 to £6,000.

The installer of a CP must notify the DNO within 30 days about the installation. DNOs offer self-service tools to enable this, for example: UK Power Networks' Smart Connect https://www.ukpowernetworks.co.uk/smart-connect and SSEN's Online Applications portal https://www.ssen.co.uk/Forms/Onlineapplications/.

2.2 Financial business case for transition

Once the connection costs and their potential implications on the configuration of assets are understood, the financial business case for transition can be revisited. Most organisations consider the TCO of an electric fleet compared to an ICE fleet over a specific period.

The value that smart optimisation can add to the business case should be considered at this stage, as this will inform the capabilities (and cost) of infrastructure and control systems that will be required. Smart charging can add value through:

- **Reducing the CAPEX of the new connection or connection upgrade, where a lower firm or a profiled connection is enabled.** Currently non-domestic customers connecting to distribution networks face an upfront charge made up of the cost of new assets needed to connect to the existing network, and a contribution towards the reinforcement of existing shared network assets, where this is required. This up-front charge may, in the future, be reimbursed by new customers connecting (so-called 'second comers'), but currently the connecting party that triggered the reinforcement bears the investment risk. Under these arrangements, a lower connection ASC may result in a lower upfront cost by avoiding the need to trigger reinforcement[10]. Regardless of the cost allocation, profiled connections will still be beneficial, because they will allow the accommodation of more demand on the network without reinforcements, thus reducing the socialised cost paid by all the network users. In constrained locations, there could be benefits in terms of speed of connection for fleets willing to accept a profiled connection.
- **Reducing the cost of charging** by ensuring the vehicles are charged efficiently at times when electricity is cheapest (i.e. utilising time-of-use or a dynamic tariff linked to wholesale energy market prices)
- **Enabling additional revenue from flexibility services** by varying the time and/or rate of charging based on 'turn down' signals from the electricity networks, and receiving a payment for this service.

The potential contribution of these value streams is further discussed in the TCO analysis in Section 3.

2.3 Business change

An electrification project crosses functional boundaries within an organisation and involves functions such as fleet management, energy management, facilities, operations, procurement, finance and HR. It is useful to ensure organisational 'buy-in' and build a broad coalition of internal stakeholders early on in this process to ensure smooth implementation and operation.

Operational departments, in particular, should be involved at the high-level feasibility stage. In some cases it may prove more economic to change operational practices to reduce costs of electrification.

Operational staff at sites play an important role in ensuring the effective management of charging and optimisation. For example at the Royal Mail delivery offices, it is necessary for the delivery office managers to ensure that the Radio-Frequency Identification (RFID) tags are correctly allocated and kept with each EV to ensure that the correct vehicle is identified when plugged into a CP. Delivery office managers are not responsible for the profit and loss account of their depot, as energy bills and connection costs are handled centrally, so they are not usually incentivised to modify their depot operations to save energy costs as is the case with smart charging. To overcome this, Royal Mail has invested time in educating delivery office managers in the benefits of a cleaner fleet to drivers, customers and the business – this has helped build understanding in the importance of managing the EV charging process effectively.

[10] Ofgem is currently consulting on proposals to reform these upfront charges for demand customers to facilitate the electrification of transport and heating under the Access and Forward-looking Charges Significant Code Review https://www.ofgem.gov.uk/publications/access-and-forward-looking-charges-significant-code-review-updates-our-minded-positions [Accessed on 17.02.2022]

The Optimise Prime project experience suggests that involving drivers early in the process is beneficial. For example, Royal Mail engaged extensively with the unions and depots, and provided driver familiarisation training. The training is provided by an external agency and its cost is similar to ICE driver training. The time commitment for new drivers is approximately three hours, a change-over training for ICE drivers transitioning to EV takes one and a half to two hours. The benefits of this approach came through in the Optimise Prime driver questionnaires, with 94% of Royal Mail EV drivers stating in the first questionnaire that sufficient support was provided and generally high level of support for the transition. Through early engagement with their engineers, British Gas also built up a significant level of support and interest in EVs, with the number of those interested in transitioning to an EV exceeding the number of available vehicles (see Behavioural analysis in Section 4.2.1).

2.4 EV Rollout plan

During the feasibility stage, an initial rollout plan and electrification timeline should be developed. This could include piloting the solution in selected locations prior to rolling out across all sites or electrifying the most suitable routes first across the whole estate. In their wider rollout plan beyond Optimise Prime, Royal Mail identified suitable sites and prioritised them based on several business-specific operational criteria with the view to maximise EV miles driven and the number of EVs across the estate. Benchmark cost per parking bay was used to exclude sites where electrification was not economically viable, primarily due to high network connection costs following initial engagement with the DNOs. The initial rollout will include cabling and electricity distribution network connections needed for full electrification, while CPs are going to be rolled out gradually in line with vehicle replacements.

The prioritisation could also be informed by the availability of data, with well understood locations electrified first, in parallel with monitoring and data collection activities across sites where insufficient information is available.

2.5 Detailed planning and procurement

Key activities in this stage include site surveys and procurement of the different components of the solution. A detailed site survey may uncover considerations that will lead to changes of the rollout plan. For example, the cost of renewing the electrical installation may limit the number of CPs that are economically feasible on a site.

2.5.1 Site surveys

Royal Mail's experience has shown that the importance of detailed site surveys, particularly on older sites with a history of change, should not be underestimated. (Deliverable D3: 3.2.3.1)

Comprehensive site surveys should consider the location of CPs and the ability to route cables to the connection point, as well as options for communications infrastructure. Depending on site design, certain operations may need to be moved to alternate areas to allow for easier cable routing. Table 8 provides an overview of the key items a site survey should consider.

Table 8 – Site survey considerations

Site survey item	Considerations
Preferred location of the CPs	• Determine the location of the CPs with respect to the electrical intake, parking spaces and access, both during construction and for maintenance • Consider the distance between distribution boards and CPs, the cost of cabling and any obstacles that may prevent connection • Is the road surface in a good condition? What is the ground surface? • Obtain site services drawings for locations of underground services
Electrical Connection points	• Assess location of electrical connection point • Assess cable route • The cost of installing CPs remote from buildings (e.g. on pillars in car parks, which require ground works; cable trenches) can be significantly more than wall mounted devices and cables in existing cable trays • Assess if there is any ducting that can be re-used • Assess location of the metering cabinets • Is a new substation required on site? Where would that be located? • Check existing earthing.
Electrical survey	• Ensure that the load of the CPs is within the limits of the circuits and DNO supply capacity • Where there are not sufficient spare breakers additional distribution boards may need to be installed • Assess supply capacity by the size of main incoming cable • Assess maximum demand through electricity metering • Assess main distribution board and sub distribution boards for rating and spare ways • Assess the space in the switch room for the new EV distribution board • Obtain site electrical schematic • Assess earthing arrangements
Reverse parking impact on parking space size	Many depots require vehicles to reverse park. The additional space required for this (approximately 20%) needs to be considered, together with the appropriate placement of the CP to connect safely to the vehicle's charging post
Signage	May be required to prevent use of EV bays by ICE drivers, or to remind drivers of charging procedures
Bollards/bump strips/CP protection barriers	To ensure that vehicles line up to the CPs correctly and do not accidentally damage the CPs
Connection to Building Management System (BMS)	Connection to the BMS should be considered to enable optimisation. Site load data from the BMS will be required to understand the capacity available for EV charging on the depot's electrical connection. If BMS is not available, the survey should consider the feasibility of installation of building load monitoring equipment
Construction access/ materials storage	A plan will be needed for the installation of the CPs without interrupting day-to-day operations
Data networking	• Assess GSM coverage & under/over ground parking • Assess data networking requirements and connection for the communication between the CPs and the back office • For some locations ethernet connection may be more suitable (with additional costs for installation) or signal boosters may be required.

Site survey item	Considerations
Data usage on SIMs	Optimisation may require more frequent communication with CPs, resulting in additional costs if using mobile data

The survey is usually conducted by the supplier selected to install the infrastructure. However some organisations may choose to have the survey conducted by their general electrical contractor, prior to procurement. In the case of Royal Mail, the surveys were conducted by two different contractors due to the volume of work, each of the contractors covered different sites. The surveys took place after CP procurement and one of the contractors was also the supplier of CPs across all sites.

Futureproofing the electricity distribution network connection and cabling installation should also be considered at this stage. Even if the rollout of CPs is conducted in stages, the total future electrical demand and cabling needs should be considered early on to avoid the need for retrofit/increasing connection capacity at a later stage at a higher cost.

Based on the site surveys, formal connection applications can be submitted to the DNOs, where required, to obtain final quotations for any upgrade. While early discussions with the DNO to obtain budgetary estimates for the connection, a binding quotation will only be provided based on an application formally submitted. Depending on the nature of the upgrade, this will typically involve contestable and non-contestable work. The former can be delivered by the DNO or an accredited Independent Connections Provider (ICP), while the latter must be conducted by the DNO.

2.5.2 Procurement

An increasing number of suppliers on the market provide comprehensive fleet electrification solutions including installation, commissioning, operation, and maintenance. Alternatively, the different components of the solution can be procured separately, and project managed by an in-house team. Agreeing an approach early on is key to designing an effective procurement strategy.

A mixture of these approaches were applied by Royal Mail and Centrica. For example, in terms of communications infrastructure, the preferred installation route for Royal Mail was to place a turnkey contract for the installation, commissioning, operation and maintenance of the on-site communications infrastructure (Deliverable D3: 3.2.3.2).

Alternatively, an approach of dividing the work according to area of responsibility and assigning one party as the lead responsible party for coordinating the sub-activities can be applied. In this case, contract coordination effort and impact on future support arrangements should be considered (Deliverable D3: 3.2.3.2).

2.5.2.1 Hardware and software procurement

This section provides guidance on the aspects that should be considered while procuring the key components of the solution, with focus on what is required to make the most of smart optimisation, building on lessons learned described in Deliverable D3. Procurement of vehicles and financing options for vehicles and infrastructure are not discussed in this document, as they are broadly similar to those for existing ICE vehicles.

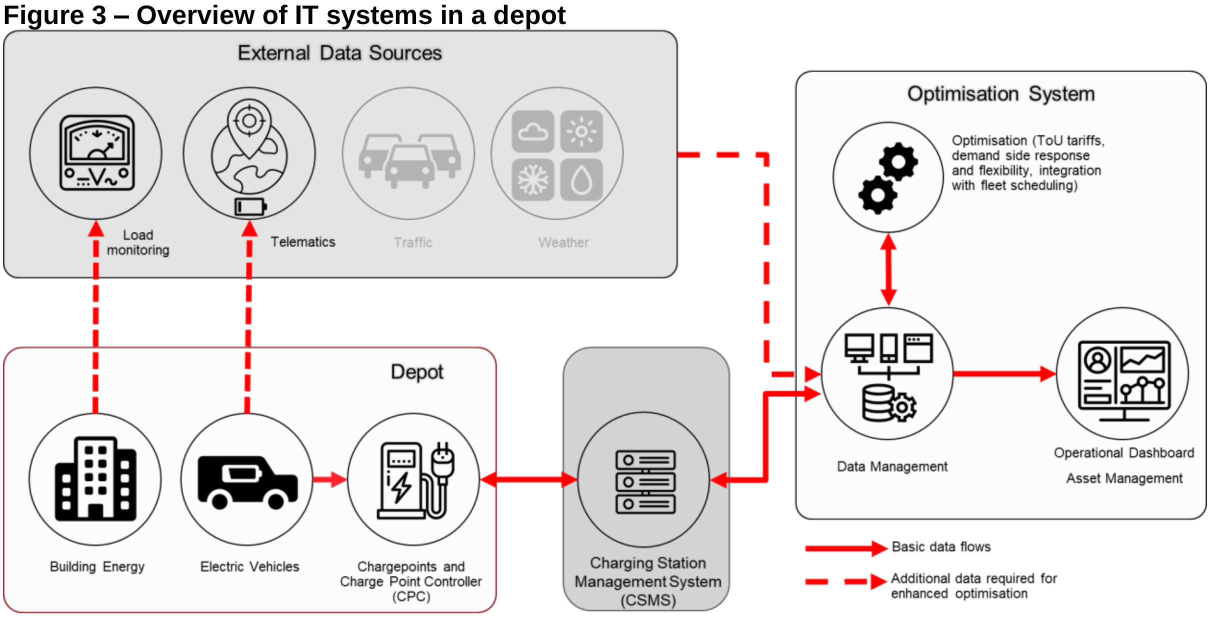
Table 9 – Considerations for electrification solution enabling efficient smart charging

Solution element	Considerations
CPs and CPC (Charge Point Controller)	• Centrica carried out an evaluation of CP models. Key procurement criteria were interoperability, Measuring Instrument Directive (MID) compliant metering, for recording fleet energy usage, including use of RFID, supplier track record and price (Deliverable D3: 2.2) • The CPs should be designed/procured together with the control system, to simplify the process of integration, as retrofitting can create significant complexity (Deliverable D3: 3.2.3.1) • Vehicle identification method should be considered. Ideally this should be done directly with the vehicle e.g. via the Plug and Charge standard, part of ISO 15118. However, as the rollout of this standard is at an early stage, use of RFIDs may need to be considered and processes put in place to manage the RFID tags.
CSMS (Charging Station Management System) or Backoffice system (terms used interchangeably)	• Ability to communicate over Open Charge Point Protocol (OCPP) between the CP and the vehicle, to support operations and maintenance functionality and remote firmware updates • The CSMS can be tied to a CP vendor or be provided by an independent vendor for future flexibility. The latter is likely to make future integration of CPs from other vendors easier • CSMS may include basic load balancing to ensure a specific load is not exceeded
Optimisation system	• This covers optimisation over and above the capabilities offered by a CSMS and may include: minimising energy costs by taking account of a Time-of-Use (ToU) tariff, integration with telematics to take account of the vehicle State of Charge (SoC), using the fleet schedule to prioritise charge to the vehicles that need it most urgently • Ability to integrate with telematics to enable prioritisation of charging individual vehicles or groups of vehicles – see Deliverable D3: 3.3.3.1 for considerations regarding telematics integration • Ability to receive and respond to flexibility requests by changing the planned charging times, within operational boundaries. This will be needed to enable demand response and generate additional revenues from providing flexibility to the DNO and/or National Grid. • Ability to optimise against a ToU electricity tariff and/or carbon intensity. More advanced systems may be able to optimise against a dynamic tariff, such as Octopus Agile, or pricing signals provided by an Aggregator. In the latter case, the Aggregator would typically have their own CSMS and would be acting as a CPO.
Site monitoring	• Required to optimise site load and charging load within the connection limit • Real time monitoring is of value especially on sites with unpredictable/ irregular baseload • May require multiple metering points, depending on complexity/age of the site • Ability to measure voltage and power factor will enable a higher level of accuracy, however monitoring current is usually sufficient
Communications infrastructure	• Communications – although coming with a higher up-front cost a common Local Area Network (LAN) connection was found by Optimise Prime to be a more reliable solution for depots than mobile cellular communications. Also, this can reduce ongoing comms costs for larger installations • Centrica opted for mobile cellular communications for the driver’s homes, because using the drivers’ broadband via a Wi-Fi connection was not deemed sufficiently reliable (because it might be turned off)

Solution element	Considerations
	• If the CPs are managed by a CPO, they may specify how the CPs connect to the CSMS
Telematics	• Telematics provides operational benefits, such as notification of vehicle faults, and being able to infer driver behaviour for the purposes of driver training/feedback • For the purposes of charging management, the management/optimisation system needs to be kept up to date with all EVs and CPs in operation– the more accurate the vehicle schedules, the higher the benefits of optimisation • Most telematics providers provide solutions for both ICE and EV vehicles. EV telematics should additionally provide details of EV specific metrics such as battery SoC and plug in/out events. • For AC CPs, SoC is not visible via a CP; for DC CPs SoC may be obtained directly via the CP. Therefore, to infer the state of charge of vehicles, the optimisation system might have to rely on telematics data
Current limiting device	• This might be required by the DNO to ensure the integrity of the electricity network. The G100 device limits the power draw by automatically disconnecting some of the site load when the ASC is exceeded. This will need to be agreed with the DNO on case-by-case basis and would typically be procured by the installer
Low carbon technologies (LCTs) – solar PV and batteries	• Integration with the optimisation system for the purposes of whole-site optimisation should be considered – using multiple vendors will make integration more complex
Fuel card/charging cost reimbursement system	• A system to monitor and enable the reimbursement of the cost of charging at drivers' homes and at public charge – see section 2.3 of Deliverable D3 for details • The system should be capable of seamless integration with the expenses/accounting system of the fleet operator, reducing the cost of the process

The solutions elements above can be combined into an overall IT system for managing the fleet and infrastructure on site, as illustrated in Figure 3.

Figure 3 – Overview of IT systems in a depot



The above requirements are based on the experience from the Optimise Prime project, which did not test V2G or provision of flexibility services to the National Grid (e.g. frequency services). Also, the project did not include traffic or weather data as external data sources, to manage depot charging, however they could be used to further improve optimisation. These may create additional requirements, going beyond the capabilities of the systems tested on the project.

2.5.2.2 Energy procurement

Additional electrical demand from depot-based EV charging may significantly increase electricity demand and cost across the estate. This may be a good opportunity to review energy procurement practices and look for a supply arrangement better aligned with organisational goals, be it cost reduction, risk management or achievement of emission reduction targets.

A business electricity bill is comprised of two major components: the commodity cost (cost of electricity) and non-commodity costs, also referred to as “pass-through charges” including government levies and charges for the use of electricity transmission and distribution networks. These pass-through charges are driven by regulation and therefore mostly independent of the choice of energy supplier. However, some of these costs are calculated retrospectively on an annual/periodic basis and are not known to the supplier ahead of time. This may lead suppliers to include a risk premium in the energy price to account for this uncertainty. The commodity cost can be highly variable in the wholesale markets. The extent of exposure to this variability and hedging strategies will depend on the type of commercial arrangement with the electricity supplier.

While energy procurement was outside of the scope of Optimise Prime, generally the following options are available to larger users:

- **A fully fixed price contract:** a contract from a supplier which is fixed for an agreed term and all commodity and pass-through costs are included in the price. This provides a cost certainty for the contract duration but is likely to include the supplier’s risk premium as they do not know how pass-through charges or Renewable Energy Guarantees of Origin (REGO) prices will change during the contract term. REGOs are issued whenever renewable energy is generated, but are traded separately to electricity. Suppliers can provide REGO-backed electricity tariffs, i.e. tariffs offered as renewable tariffs, whereby the supplier purchases the appropriate amount of REGOs.
- **A flexible contract:** a contract from a supplier that offers a framework to buy energy when the market price is right for the customer. Managing such a contract requires expertise, either in-house or from a specialist intermediary, but may result in savings by lowering the commodity cost and the risk premium related to non-commodity price components. The customer takes on the risk of pass-through charges variability, but pays only for the charges applied, without the additional risk premium.
- **A Power Purchase Agreement** (PPA)/**Corporate Power Purchase Agreement** (CPPA): a contract between a power producer, such as wind or solar farm, and a corporate off-taker. The PPA defines the conditions of the agreement, such as the amount of electricity to be supplied, price, term, structure, and penalties for non-compliance. Since it is a bilateral agreement, a PPA can take many forms and is tailored to meet both parties’ requirements. Over recent years, corporate PPAs have become the primary route to market for new renewable energy assets and play an important role in the transition to net zero carbon. A PPA is usually approximately 10 years in duration and allows the buyer to lock in competitive prices over that term, providing certainly over the commodity

component. While a green tariff can be achieved through REGOs, a PPA is a more direct way of enabling the building of new renewable assets.

End user approaches to hedging will reflect the size, resources and risk appetite of the organisation. Typical approaches by customer type as defined by their metering arrangement and annual demand are summarised in Table 10.

Table 10 – Typical electricity contracting approaches by customer type

Customer Type	High-level classification (SME, Mid-Market, I&C)	Typical contract type	Hedging by
NHH 1-2	SME (PC1 and PC2 also include domestic)	Fixed price proposition; typically fully inclusive tariff; limited potential for passthrough of third party charges (TPC); renewable energy as an option	Supplier under fixed tariff proposition
NHH 3-4			
HH <1GWh	SME to Mid-Market	Fixed price, but with application of flexible at aggregated level; growing potential for TPC passthrough; renewable increasingly as standard	Supplier, third party intermediary or aggregator
HH 1-10GWh		Emergence of flexible contracts; renewable as standard; TPC passthrough	
HH 10-30GWh	I&C	Flexible contracts as standard (trading desk access); renewable as standard; TPC passthrough	Supplier (under delegated authority), third party intermediary or aggregator Larger energy intensive users may have dedicated in-house resource
HH 30GWh+		Flexible contracts as standard (trading desk access); renewable as standard; TPC passthrough; PPA and CPPA at larger end of the market	

Source: Cornwall Insight, October 2020

Royal Mail fall into the largest user category with a total demand over 30 GWh per year across multiple sites. With strategic priorities of ensuing cost certainty and converting to renewable energy, Royal Mail are currently reviewing the procurement strategy considering the impact of EVs.

The contract provisions will define the price of electricity paid by the site at different times of the day, ranging from a flat tariff (a fixed price per kWh of electricity, regardless of when it is used) to a ToU tariff with two or more fixed time bands throughout the day, to more variable arrangements. Most business tariffs fall into the ToU category.

The different time bands of the ToU tariff can be utilised by an EV smart charging system to minimise the cost of charging.

For example, the tariffs at Royal Mail depots during the project had five different time bands during the weekdays, with the cheapest rates between midnight and 06:30, allowing the vehicles to recharge overnight at low cost. The most expensive time bands were 11:00 to 14:00 and 16:00 to 19:00, reflecting the high DUoS (Distribution use of System charges, a component of the non-commodity cost) during these times of peak network use in UK Power Networks' area. The TCO analysis (Section 3) illustrates the savings resulting from tariff-based optimisation.

For home-based fleets, the CP installed at an employee's home will be on the same supply point/meter as the rest of the demand in the home. It is therefore difficult to advise the employees to change their domestic tariff to optimise the cost of EV charging, as this will impact on the rest of their electricity bill. There is currently no industry solution enabling two different electricity tariffs on one metering point, however changes are being discussed[11] that might enable this in the future.

Centrica have decided not to advise their drivers to switch their domestic tariffs, but a process was put in place to verify the tariffs and keep them up to date for reimbursement and optimisation purposes.

2.6 Deployment and Commissioning

This phase covers the installation, testing and commissioning of hardware and software. In addition, it should include staff training and any relevant changes to internal processes, policies and procedures. This may include instructions for drivers on when and where to plug in to improve predictability of charging patterns.

For fleets that require public charging, arrangements with public charging networks may need to be made. Initially, this was not required in the case of Royal Mail's return-to-depot model, as depot charging fully meets the requirements, although using public charging providers at some locations is being considered as electrification progresses.

In Centrica's case, public charging is required for drivers with larger patches, where the range of the vehicles may be insufficient for a whole day's work, as well as for those who do not have access to off-street parking where a CP can be installed. To address these issues, Centrica have developed the 'virtual fuel card', which is now a commercial offering.

The following lessons learned from the project relate to this phase and are described in more detail in Deliverable D3 (section numbers in brackets):

- There can be a complex range of actors involved in the provision of depot charging, such as CSMS providers, facilities, depot operator, property, energy, procurement, drivers, and IT systems maintainers, and it is essential to clearly define responsibilities during both the installation and operational phases (3.2.3.3).
- Where there are multiple Meter Point Allocation Numbers (MPANs) at a site, the CPs should be recorded against which MPAN they are connected to at the time of installation (3.2.3.1). This will be relevant for the design of profiled connection and optimisation within a profile on a given meter point.
- Power infrastructure at larger and older sites can be complex and require additional time and resources to implement successfully (3.2.3.4).
- If a profiled connection or lower firm connection is agreed with the DNO, requiring smart optimisation to stay within the ASC, the DNO is likely to require a monitoring device to be installed at the depot operator's expense, on the DNO side of the meter. Experience from the Royal Mail trials shows that it is not always possible to install point of connection monitoring within distribution network infrastructure and installing on customer premises can be complex (3.4.1). This should be considered during surveys and deployment planning.

[11] P375 'Settlement of Secondary BM Units using metering behind the site Boundary Point' https://www.elexon.co.uk/mod-proposal/p375/

- Vehicle identification/RFIDs – the use of RFID tags to identify which vehicle is using which CP within a depot is not always reliable, as tags could be swapped, get lost and replaced or drivers may not authenticate the charging session properly. Tighter vehicle and CP integration (where the vehicle itself identifies to the CP) would make optimisation of charging more reliable, simpler to implement and operate (3.2.3.1). If possible, vehicles and infrastructure compliant with the Plug and Charge standard should be selected. If not available, effective operational procedures to manage RFIDs should be put in place
- There may be a lack of consistent routines/policies for charging vehicles at the end of shift, and these will need to be put in place to get the most out of smart charging (3.2.3.5)
- Early involvement of operational staff and third parties is key to ensuring that commissioning proceeds with minimal disruption (3.2.3.3).

2.7 Operation and Optimisation

An Operations and Maintenance (O&M) contract will be advisable to set out preventative and corrective maintenance Service Level Agreements (SLAs), the process for 1st, 2nd and 3rd line support for the CPs, once installed. This will ensure effective monitoring and resolution of CP faults.

In addition to the standard fleet management activities, the resources/capabilities required for following need to be considered:

- Contract management and coordination between suppliers – especially if the different elements of the solution are procured separately.
- Processes to ensure that details of all assets are up to date (Deliverable D3 3.3.3.1) – EVs, CPs and RFIDs (if used). This will enable effective optimisation.
- Operation of smart systems and participation in flexibility services – for organisations choosing to implement more sophisticated optimisation systems and participate in flexibility services, the effort of bidding for and managing flex contracts can be significant and require specialist expertise. This could be achieved either by building an in-house capability or contracting with a specialist aggregator. Which option is more suitable, will depend on the size of the organisation and the likely value that could be generated from flexibility provision. In the case of Royal Mail, it is estimated that once the flexibility process is up and running, approximately 0.1 fulltime equivalent (FTE) would be required to manage it across the nine participating depots, comprised of time contributed by staff at different levels (analyst, senior management, and depot managers). The potential costs and benefits of the provision of flexibility services to the DNO are discussed in more detail in the TCO analysis in Section 3. Participation in other flexibility markets was out of scope. However, a specialist aggregator would likely 'stack' revenue from different flexibility value streams (DNO, National Grid, as well as wholesale electricity markets), thus potentially enabling a higher value. Even in the case of outsourcing the flexibility management to an external party, a level of internal expertise will be required in-house to procure and manage a flexibility operator and on depot level to troubleshoot any issues and ensure that the flexibility provision does not interfere with operational requirements. As discussed in Section 7, in the mid-term such services will be fully automated, requiring only minimal oversight from the fleet operator.

Royal Mail estimate that overall, the resources required to operate an EV fleet are roughly the same as those required to run an ICE fleet (excluding flexibility management). Based on experience to date, it is expected that maintenance will require less effort as EVs break down less frequently and on-going maintenance is less time consuming. Royal Mail maintain their vehicles in-house – all the technicians underwent an on-line Level 3 training course in EV maintenance and workshops are being fitted with EV CPs.

For home-based and mixed fleets, the process of reimbursement for charging costs will need to be managed. While Centrica have largely automated the process with their Virtual Fuel Card solution integrated with payroll, some manual effort is required to keep domestic tariffs up to date for reimbursements and optimisation. For further details on solutions enabling the separation of commercial load on domestic connections, see Section 6.

3 Economic Findings

3.1 TCO Model Introduction

3.1.1 Purpose

The TCO compares the cost of acquiring and operating an ICE vehicle and an electric fleet over its lifetime and is a key component of the business case for transition to EV for most organisations.

The purpose of TCO modelling is to demonstrate, 'like for like', a complete cost comparison between an ICE fleet and a fully electric fleet, and to explore the influence of historical and future changes in the key variables.

While at the outset of Optimise Prime it was expected that in most scenarios an EV fleet TCO should be at least at parity with an ICE fleet, if not lower, changes to external factors over the course of the project have made this picture more nuanced. The TCO models presented in this section explore the impacts of such changes, including increases of electricity and fuel prices, vehicle costs, as well as changes to government policies. The influence of the methods trialled under Optimise Prime (profiled connections, flexibility provision and smart optimisation) will also be discussed, appreciating that trials are still ongoing and not all variables could be quantified at this stage.

3.1.2 Approach

The overarching approach to all the TCOs presented in this section is common, with some differences resulting from varying characteristics of the three fleet types, as outlined below.

The key components of each TCO model are: total CAPEX, operating expenditure (OPEX), and relevant revenue streams. The latter may include the resale value of vehicles, as well as additional revenue generated from the provision of flexibility services to the DNO (Table 11). This section provides an overview of the main TCO components and the sources of the assumptions for each of the project partners. While efforts were made to use real partner data as basis for the TCO inputs, in some cases this was not possible (because of partner confidentiality) or deemed not representative. For example, negotiated vehicle prices leading to lower CAPEX for project partners, were replaced by market benchmarks to show a realistic CAPEX achievable by an average-sized fleet.

Table 11 – Overview of TCO components and data sources

Input data	Data sources
CAPEX Vehicle acquisition (if vehicles purchased) CP acquisition Distribution network connection LCT) acquisition (if relevant)	Manufacturer list price Manufacturer list price Depot Planning Model (the model behind the project's Site Planning Tool); UK Power Networks' cost data Manufacturer list price
OPEX Vehicle lease cost (if not purchased) Electricity Public charging Maintenance (vehicle) Maintenance (CP) Control software	Assumed to be 2% of list price per month Published flat and Time-of-Use tariffs Published membership fees Published vehicle maintenance cost data Published maintenance cost data Assumed 10% of CP cost Published average vehicle insurance data

Input data	Data sources
Insurance Tax Tolls	Published excise duty rates Transport for London (TfL) Low Emissions Zone, Ultra Low Emissions Zone, Congestion Charge and Zero Emission Zone data
Revenue Vehicle resale value (if vehicles purchased) Flexibility Third party flexibility management fee Onsite electricity generation	Published data on vehicle end of life value UK Power Networks' LV flexibility value data Market benchmark for an aggregation fee Depot Planning Model

For both ICE and EV fleets there are two possible ownership strategies: outright purchase or leasing. For the former, the vehicle acquisition is a CAPEX cost, with any end-of-life value of the vehicle treated as a revenue stream for resale. For leasing, the fleet costs are all OPEX costs.

EVs require charging infrastructure, which could be installed at a depot or a driver's home, either through outright acquisition or a leasing method. Additionally, the fleet could also use public charging infrastructure, requiring membership of one or more CPO schemes. The CP requires maintenance and could also require a control software package to enable smart charging.

The outputs of the TCO model include: cumulative TCO over the selected time period for both ICE and EV fleets, the Net Present Value (NPV) and Internal Rate of Return (IRR) for investment in electrification.

If LCTs, such as solar PV are installed, there is also the potential to consume electricity generated onsite rather than from the grid, and to export excess production to the grid at a given rate per kWh exported.

The TCO scenarios explored are as follows:

- **Royal Mail's** TCO considers nine depots in the trials individually because some of the assumptions are location specific (e.g. connection costs, applicability of Congestion Charge, mileage driven). These results are then consolidated to show the TCO across all of the nine depots. The TCO is calculated over eight years and assumes the outright purchase of vehicles and charging infrastructure. The impact of network connection upgrade costs, changes in vehicle and fuel prices, congestion charges and potential flexibility revenues are discussed. The benefits of solar PV installation are quantified for one of the depots (Islington), which has an existing rooftop installation.

- **Centrica's** TCO is based on a five-year leasing model for the vehicles and the infrastructure. Results are shown for a single vehicle and extrapolated to the whole of the British Gas fleet. This was possible because home-based installations, unlike depots, do not attract location-specific connection costs. However, as British Gas' fleet electrifies fully, it is expected that approximately 60% of drivers will rely on public charging, due to the feasibility of installing a CP at every home. The TCO explores the impact of different mixes of charging scenarios, as well the recent changes in electricity and public charging prices.

- In the case of **Uber**, the decision to transition to EV is an individual decision for each of the drivers, and the TCO balance may change depending on the individual circumstances of the driver, e.g. mileage driven, access to finance, ability to install a home CP, as well as vehicle type selected. The TCO employs a persona approach and explores different scenarios for the most representative driver personas constructed based on behavioural questionnaires and feedback from Uber.

The following sections present TCO results for these three trials. In addition to the financial impact, CO2e savings resulting from the transition are calculated based on operational emissions (excluding other lifecycle emissions resulting from the production and disposal of the vehicles and the infrastructure).

3.2 Total Cost of Ownership for depot-based fleets – an example from Royal Mail

3.2.1 Overview of the Royal Mail TCO Model

The Royal Mail TCO aims to illustrate the cost of the fully electrified fleet versus fully petrol/diesel fleet, using the examples of the nine Royal Mail depots in the trials. Unlike for Centrica's TCO, no extrapolations were made to other depots, as the cost components related to depot distribution network connection reinforcement are location-specific. The model focuses both on the investment aspects and the impact on CO_2e emissions.

Royal Mail vehicles are currently being charged solely at the depots with no public or home charging. The depots in scope differ in size based on vehicle numbers, vehicle type, average yearly milage per vehicle, and existing ASC, which allows the impact of these variables to be assessed.

The aim of the TCO is to reach conclusions applicable to other depot-based fleets, while retaining the important characteristics of the Royal Mail depots. For example, vehicle prices are based on benchmark values, accessible to a mid-sized fleet rather than discounts available to Royal Mail. The mix of vehicles has also been simplified to two comparable vehicle types only (Peugeot Partner, Peugeot Expert and their electric equivalents).

All depots are based in London where EVs are exempt from the congestion charge until 2025. From 2025 all vehicles are assumed to be subject to congestion charging, removing this source of cost saving from EV transition. The model does not explore any potential changes to road taxes currently under discussion. It has been assumed that all vehicles in the model will operate in the congestion charge zone, although in reality this varies by depot and vehicle route.

3.2.2 Assumptions

The assumptions in the TCO model were necessary to be able to compare scenarios of 100% ICEV fleet and 100% of EV fleet. The assumptions are based on inputs from the Royal Mail trials, publicly available data or benchmarks.

Table 12 shows the assumptions common across all TCO models presented in this section and Table 13 those that are specific to Royal Mail.

Table 12 – TCO key assumptions[12]

Key assumptions	Inputs		Source	Cost type
Fuel cost - diesel (£/l) 2022	**£1.50**		Benchmark Price https://www.confused.com/on-the-road/petrol-prices 28/01/2022	OPEX
Fuel cost - diesel (£/L) 2021	**£ 1.31**		Benchmark price https://www.confused.com/on-the-road/petrol-prices 2021	OPEX
Fuel cost - petrol (£/L) 2022	**£1.46**		Benchmark price https://www.confused.com/on-the-road/petrol-prices 28/01/2022	OPEX
Fuel cost - petrol (£/L) 2021	**£1.26**		Benchmark price https://www.confused.com/on-the-road/petrol-prices 2021	OPEX
Electricity cost 2022 (£/kWh)	**£0.23**		Benchmark price Love Energy Savings (powercompare.co.uk)	OPEX
Electricity cost 2021 (£/kWh)	**£0.15**		Benchmark price Love Energy Savings (powercompare.co.uk) 2021	OPEX
AdBlue (£/km)	**£0.0030**		Based on £1.50/l and 1l per 500km	OPEX
Inflation	**1.5%**		Common assumption across all TCO models	OPEX/CAPEX
Daily congestion charge (£) pre-2025	**ICE** **EV**	**£15** **£0**	https://tfl.gov.uk/modes/driving/congestion-charge/paying-the-congestion-charge = 18/02/2022	OPEX
Daily congestion charge (£) 2025 onwards	**ICE** **EV**	**£15** **£15**	https://tfl.gov.uk/corporate/transparency/freedom-of-information/foi-request-detail?referenceId=FOI-0573-2021 18/02/2022	OPEX
Carbon emission (kg CO_2/L of diesel	**2.66807**		https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021 18/02/2022	-

Table 13 – Depot key assumptions

Depot key assumptions	Inputs		Source	Cost type
ICE vehicle cost (£)	**Peugeot Partner**		Specific value redacted due to commercial confidentiality	CAPEX
	Peugeot Expert			
ICE fuel efficiency (l/km)	**Peugeot Partner**	**0.06**	https://www.peugeot.co.uk/ based on WLTP[13] 18/02/2022	OPEX
	Peugeot Expert	**0.073**		
ICE maintenance costs (p/m)	**Peugeot Partner**	**£3.44**	Benchmark price https://www.commercialfleet.org/tools/van/running-costs	OPEX
	Peugeot Expert	**£3.44**		
EV vehicle costs (£)	**Peugeot ePartner**		Specific value redacted due to commercial confidentiality	CAPEX
	Peugeot eExpert			

[12] Prices used in this analysis were sourced in January and February 2022. It should be noted that there have been significant increases in electricity and fuel prices since this time which may impact upon future TCO analysis

[13] WLTP (Worldwide Harmonised Light Vehicle Test Procedure): https://www.wltpfacts.eu/

Depot key assumptions	Inputs		Source	Cost type
	Mercedes eVito			
EV power efficiency (Wh/km)	**Peugeot ePartner**	**262**	https://www.peugeot.co.uk/ based on WLTP	OPEX
	Peugeot eExpert	**294**		
	Mercedes eVito	**370**		
ICE insurance costs (£/vehicle/year)			Specific value redacted due to commercial confidentiality	OPEX
EV insurance costs (£/vehicle/year)			Specific value redacted due to commercial confidentiality	OPEX
EV maintenance costs (p/m)	**Peugeot ePartner**	**£1.91**	Benchmark price https://www.commercialfleet.org/tools/van/running-costs/	OPEX
	Peugeot eExpert	**£1.89**		
	Mercedes eVito	**£1.89**		
ICE and EV resale value after 8 years (% of purchase price)	**10%**		Benchmark Average % https://www.kbb.com/new-cars/best-resale-value-awards https://www.forbes.com/sites/jimgorzelany/2019/03/25/heres-why-electric-car-resale-values-are-on-the-upswing/#3229eefc6af3 Not split between ICE/EV	Revenue
CPs purchase and installation costs (£/unit)	**Commercial Double Socket Charger**		Specific value redacted due to commercial confidentiality	CAPEX
CPs maintenance costs (£/Unit/Year)	**Commercial Double Socket Charger**		Specific value redacted due to commercial confidentiality	OPEX
Weighted Average Cost of Capital (WACC)	**5%**			NPV
Solar PV generation	**Solar Panels**	**62**	Based on Islington Depot N1 7ED - Google Maps 23/02/2022	CAPEX
	SP Rating (Watts)	**450**	Benchmark Average % Honey M - DE08M.08(II) | Trina Solar 21/02/2022	
	Price per kWp	**£800**	Hitachi market knowledge	
	Annual kWh generation per kWp	**900**	Hitachi market knowledge	Revenue
Flexibility	**(£/MWh)**	**£549**	Benchmark price (Utilisation price based on awarded UK Power Networks tenders available on Piclo https://picloflex.com/ - see Section 3.2.4.7 for detail)	Revenue

Table 14 details Electricity network connection assumptions and are based on the findings from initial connection analysis explained in section 3.6.3.3, of Deliverable D4 where 20 Royal Mail depots were analysed in order to ascertain the peak load from future electrification plans across depots. The results of load analysis were then assessed by UK Power Networks and estimated costs of connection were provided. This TCO analysis uses the 'base' case and 'smart' case to illustrate the differences:

- **Base:** where all CPs are used simultaneously at the time of peak background load (i.e. the worst-case scenario).
- **Smart:** where charging times and speeds were managed to below the ASC where possible.

The connection upgrade cost for Camden, Dartford and Victoria are calculated using the average ASC exceedance (kW) across 20 depots due to the lack of data for these locations.

These estimates were deemed sufficient for illustrative purposes in the current TCO. However, they may not be fully reflective of the current situation in the depots due to changes in underlying assumptions. For example, a 1:1 ratio of vehicles to sockets was originally assumed, and so in the worst-case scenario all vehicles would be charging at the same time. However, Royal Mail strategy changed, for new depots, to have a 2:1 ratio, thus reducing the CAPEX of CPs. This will need to be supported by operational changes and would result in a lower demand under the base case scenario, because not all vehicles will be able to charge at the same time. The assumptions behind reinforcement costs will be revisited in the final project deliverable, alongside the discussion of benefits of profiled connections.

When applying this TCO to other fleets and locations, it should be understood that connection costs are location dependent, based on constraints on the local distribution network. While an average from the trials sample of depots has been used here, the cost for another depot could be significantly higher if upgrades to network assets were required.

Table 14 – Network connection costs

Depot	Network Connection (£) Base Case	Network Connection (£) Optimised Smart Charging Case	Source	Cost Type
Mount Pleasant	£0	£0	UK Power Networks	n/a
Camden	£42,253	£42,253	Average cost across 20 depots analysed	CAPEX
Bexleyheath	£100,000	£0	UK Power Networks	
Islington	£85,000	£0	UK Power Networks	
Victoria	£42,253	£42,253	Average cost across 20 depots analysed	
Orpington	£168,000	£2,000	UK Power Networks	
Premier Park	£85,000	£0	UK Power Networks	
Dartford	£42,253	£42,253	Average cost across 20 depots analysed	
Whitechapel	£0	£0	UK Power Networks	n/a

Table 15 – Fleet assumptions

Depot	No. Vehicles	Assumed Vehicles		Assumed number of dual socket CPs (2:1 Vehicle: Socket ratio)
		100% ICE	100% EV	
Mount Pleasant	192	192 Expert	192 eExpert	48
Camden	37	19 Partner	19 ePartner	10
		18 Expert	18 eExpert	
Bexleyheath	23	23 Partner	23 ePartner	6
Islington	38	26 Partner	26 ePartner	10
		12 Expert	12 eExpert	
Victoria	12	3 Partner	3 ePartner	3
		9 Expert	9 eExpert	
Orpington	28	21 Partner	21 ePartner	7
		7 Expert	7 eExpert	
Premier Park	111	84 Partner	84 ePartner	28
		27 Expert	27 eExpert	
Dartford	128	72 Partner	72 ePartner	32
		56 Expert	56 eExpert	
Whitechapel	36	14 Partner	14 ePartner	9
		22 Expert	22 eExpert	

The vehicle numbers presented in Table 15 represent the mix of Royal Mail vehicles on the ground, while being representative of the choice of comparable vehicles available in the market. The aim is a representative TCO comparison, ignoring any preferential vehicle purchase conditions available exclusively to Royal Mail due to the size of their fleet. (Calculations steps can be found in Appendix 9.2).

3.2.3 Results

Table 16 and Table 17 summarise the TCO results for a fully ICE vs. fully electric fleet across the nine depots. Table 16 shows a ‘Base’ case scenario with higher network connection CAPEX costs, while Table 17 shows a ‘Smart’ charging scenario, in which the requirement for additional capacity is substantially reduced.

The NPV was calculated over eight years assuming a cost of capital of 5%. In the ‘base’ case scenario, the NPV for the nine depots was £629,000, representing the overall benefit of the transition to EV over that period. In the scenario with smart charging and the resulting lower connection CAPEX this value increases to £1,064,800 (~70% improvement in the project’s NPV).

Table 16 – Eight year view costs for 100% ICEV and 100% EV depots – Base Case

Cost \Depot £'000	Whitechapel	Camden	Bexleyheath	Islington	Mount Pleasant	Victoria	Orpington	Premier Park	Dartford	Total
CAPEX ICE	1,645	1,628	859	1,583	9,797	571	1,141	4,513	5,545	27,282
OPEX ICE	1,846	1,877	1,060	1,828	9,699	614	1,386	5,547	6,807	30,665
REVENUE[14] ICE	-84	-83	-44	-81	-500	-29	-58	-230	-283	-1,392
TOTAL ICE	**3,408**	**3,422**	**1,875**	**3,330**	**18,996**	**1,156**	**2,469**	**9,830**	**12,069**	**56,555**
CAPEX EV	2,120	2,207	1,390	2,274	11,667	757	1,768	6,428	7,474	36,086
OPEX EV	1,302	1,329	765	1,307	6,825	432	986	3,943	4,783	21,671
REVENUE EV	-103	-105	-62	-106	-568	-35	-78	-308	-361	-1,726
TOTAL EV	**3,319**	**3,432**	**2,092**	**3,475**	**17,924**	**1,155**	**2,677**	**10,063**	**11,895**	**56,031**
NPV (8-year)	**91**	**1**	**-186**	**-116**	**987**	**0**	**-188**	**-155**	**195**	**629**
IRR (8-year)	**38%**	**9%**	**-**	**-**	**64%**	**5%**	**-**	**-**	**27%**	

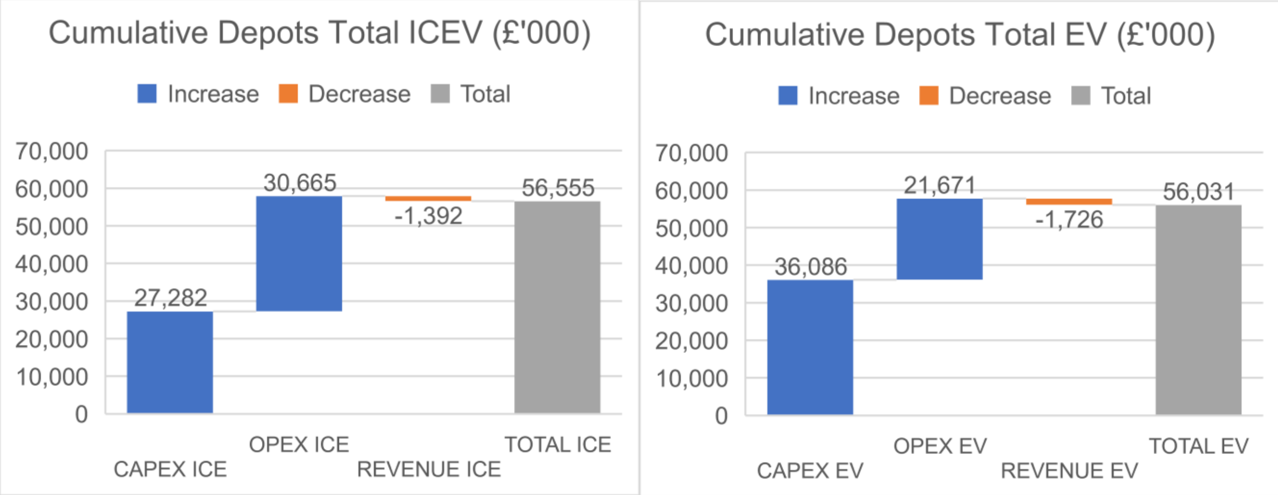
Table 17 – Eight year view costs for 100% ICEV and 100% EV depots – Smart Charging

Cost\Depot £'000	Whitechapel	Camden	Bexleyheath	Islington	Mount Pleasant	Victoria	Orpington	Premier Park	Dartford	Total
CAPEX ICE	1,645	1,628	859	1,583	9,797	571	1,141	4,513	5,545	27,282
OPEX ICE	1,846	1,877	1,060	1,828	9,699	614	1,386	5,547	6,807	30,665
REVENUE ICE	-84	-83	-44	-81	-500	-29	-58	-230	-283	-1,392
TOTAL ICE	**3,408**	**3,422**	**1,875**	**3,330**	**18,996**	**1,156**	**2,469**	**9,830**	**12,069**	**56,555**
CAPEX EV	2,120	2,207	1,290	2,189	11,667	757	1,602	6,343	7,474	35,650
OPEX EV	1,302	1,329	765	1,307	6,825	432	986	3,943	4,783	21,671
REVENUE EV	-103	-105	-62	-106	-568	-35	-78	-308	-361	-1,726
TOTAL EV	**3,319**	**3,432**	**1,992**	**3,390**	**17,924**	**1,155**	**2,511**	**9,978**	**11,895**	**55,595**
NPV (8-year)	**91**	**1**	**-86**	**-31**	**987**	**0**	**-22**	**-70**	**195**	**1,065**
IRR (8-year)	**38%**	**9%**	**-**	**-**	**64%**	**5%**	**-**	**-**	**27%**	

Figure 4 illustrates that, for ICEV, running costs over the eight year period exceed the initial cost of investment into fleet. The EV OPEX is considerably lower in comparison to EV CAPEX and ICEV OPEX.

[14] In Tables 16 and 17, 'revenue' represents the resale value of vehicles after eight years, assumed to be 10% of the initial purchase price for both ICEV and EVs. Anecdotal evidence suggests that EVs depreciate at a lower rate, however this is dependent on the model and range, and reliable market data is not available at present.

Figure 4 – Comparison of CAPEX and OPEX between ICEV (left) and EV (right) fleets



In the Base Case charging scenario for all nine depots, the initial comparison between 100% ICEV and 100% EV Fleet suggests that running a fully electrified fleet is cheaper than an ICEV fleet. However, the results are not consistent. Table 16 illustrates not only that Total ICEV and EV cost varies between depots, but also that it varies to a different degree. In five depots (Camden, Bexleyheath, Islington, Orpington, Premier Park), the EV fleet turns out to be more expensive than ICEV one.

One of the reasons for that could be higher network connection costs. However, when costs in the Smart charging scenario are investigated (Table 17), in most cases the network connection is reduced dramatically, yet overall EV fleet costs are still higher. This is due to the vehicle type in each of the fleets. These five depots have more Peugeot Partner/ePartner in their fleet than Expert/eExpert and there is a significantly greater difference in cost between the EV and ICEV Partners than between the EV and ICEV Experts.

If the cost difference across all vehicle types are assumed to be 20% higher for EVs, the results will be different. At Premier Park for example, which has a mixed fleet of ePartner/eExpert models, if all of the EVs were 20% more expensive than equivalent ICEVs there would be a positive TCO for EVs in the base case scenario. The eight year NPV would increase from -£155,450 to £332,964 and IRR becomes positive at 41%. Combining this with smart charging to eliminate connection reinforcement, the eight year NPV increases to £417,964 while IRR is 52%.

The TCO model concludes that for the ICEV and EV TCO to breakeven, the EV cannot be more than 28% more expensive than ICEV.

Connection costs will be explored further in section 3.2.4.3. Vehicle price impact on fleet will be discussed in the section 3.2.4.2.

In order to present the most realistic scenarios which could be used as benchmarks for fleet electrification, the following results are explored further for three differently sized depots: small (Bexleyheath – 23 vehicles), medium (Premier Park – 111 vehicles) and large (Mount Pleasant – 192 vehicles) depots.

3.2.4 Factors impacting the TCO

3.2.4.1 Electricity and Fuel Prices

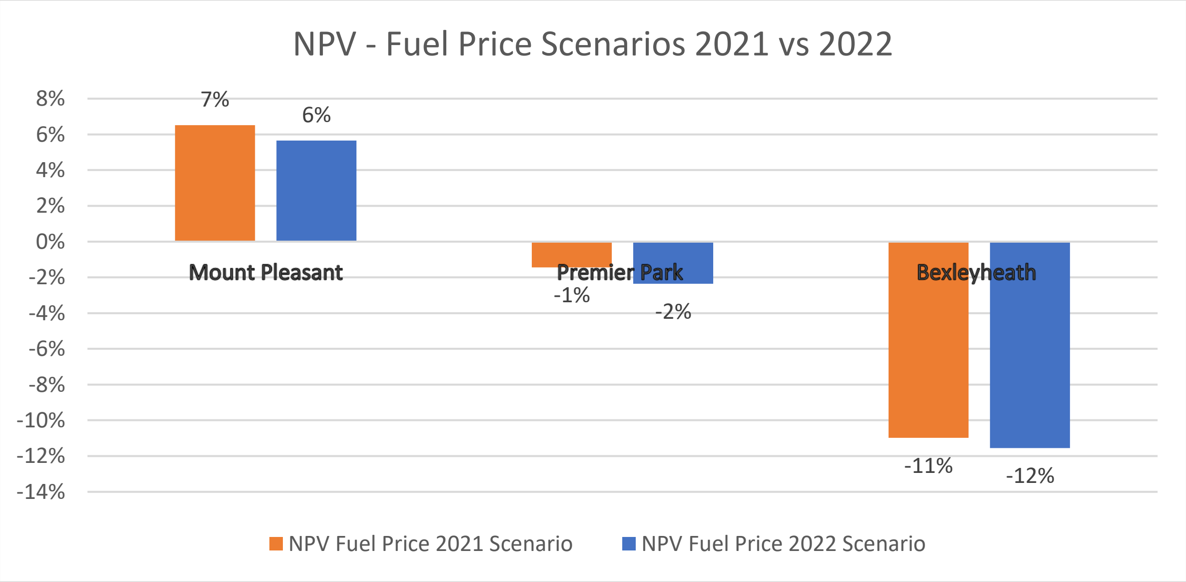
The same average per kWh electricity cost was assumed for all depots, based on market benchmarks (£0.15/kWh for 2021 and £0.23/kWh for 2022). The benefits from ToU tariff optimisation are discussed separately in 3.2.4.6. The potential interactions between smart charging, for the purposes of load reduction/profiled connections, and the ability to optimise based on ToU at the same time will be explored in the final project deliverable based on learnings from the trials.

Due to the significant increase of energy prices at the beginning of 2022, it was deemed necessary to check whether this had any impact on potential fleet electrification based on the Royal Mail model. This may be particularly significant considering that electricity prices increased by about 50% while the diesel price increased from £1.31 to £1.50 between 2021 and February 2022, a rise of 15%.

Figure 5 and Figure 6 show the eight year cumulative net savings of EV versus ICEV fleet spread across fuel and electricity prices in 2021 and 2022 for the small, medium and large depots. Figure 5 illustrate that increased prices did not have significant impact on the business case for fleet electrification. In fact, eight years cumulative saving decreased by only 1% in 2022 across the three depots. This was also the case when average yearly milage per vehicle were increased and decreased (all depots had different mileages).

This might be due to electricity prices still being cheaper than diesel prices to fuel a van, but also because there is control over the electricity tariff when the EVs are charged in a depot. Even though the tariff price was increased by 50% from £0.15 in 2021 to £0.23 to in 2022, it is still cheaper than domestic and public charging electricity prices which affect both Centrica and Uber TCOs.

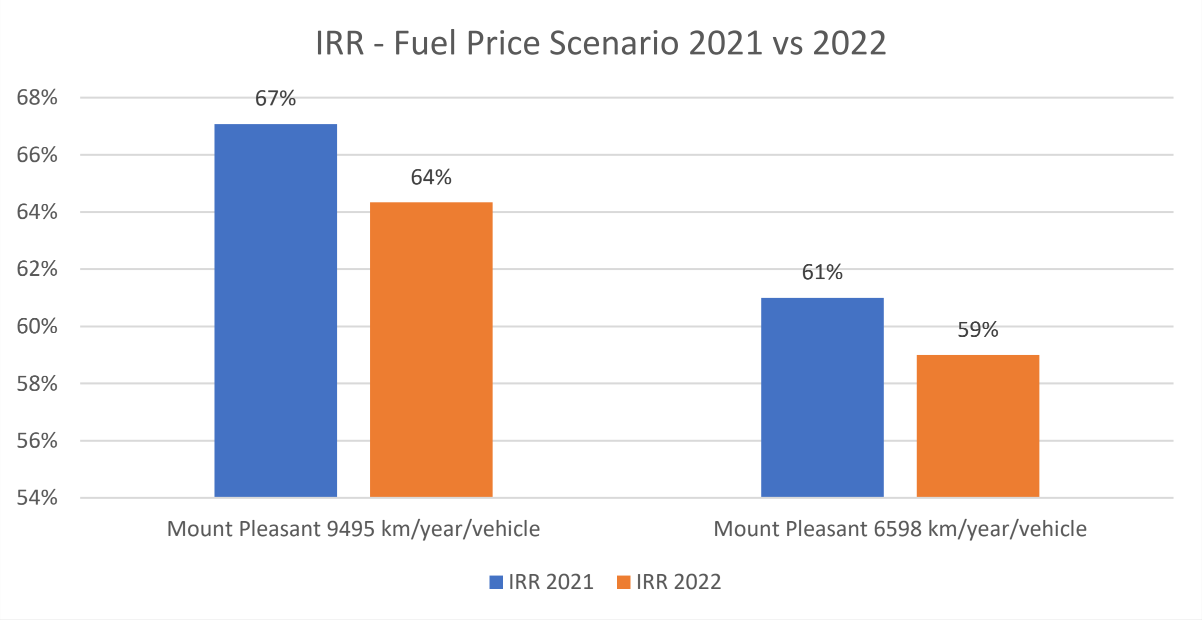
Figure 5 – Impact of fuel price change on NPV



Electricity and fuel prices had a slightly higher impact on IRR. In the Mount Pleasant example, which is the only one out of the three with positive IRR, the increase in prices reduced the eight year IRR from 67% in 2021 to 64% in year 2022 (Figure 6). In this scenario a typical distance travelled of 9,495 km/year/vehicle was considered. However, if this distance is reduced to 6,598 km/year/vehicle, as in Bexleyheath, which has the lowest distance across the depots, then the eight year IRR is at 61%, with 2021 prices, and drops to 59% in year 2022.

The conclusion is that while electricity price difference had a more of a negative impact on IRR than on Cumulative Net Savings, it did not have a major impact on the overall TCO even with the different distance scenarios (2021 IRR difference 3% and 2% in 2022). The distance travelled significantly influences the IRR: the higher the distance per depot, the higher the IRR which is linked to the overall lower OPEX costs of EVs.

Figure 6 – Impact of fuel price change on IRR



3.2.4.2 Vehicle Prices

Figures 7,8 and 9 illustrate the breakdown of costs for the ICEV and EV fleets. The most significant difference between ICEV and EV CAPEX is at the smallest depot, Bexleyheath (62%), and the smallest difference at the largest depot, Mount Pleasant (19%).

One of the biggest drivers of this difference is vehicle type. For Mount Pleasant, calculations are solely based on Expert vs eExpert vehicle type. For Bexleyheath, calculations are based on Partner vs ePartner The price differential between ICEV and EV is significantly higher for the smaller Partner vehicle. Premier Park's fleet includes both types of vehicles, however with a larger number of the Partner/ePartner model the CAPEX model aligns more closely with Bexleyheath.

Figure 7 – Mount Pleasant – Fleet cost breakdown based on Expert/eExpert – Base case

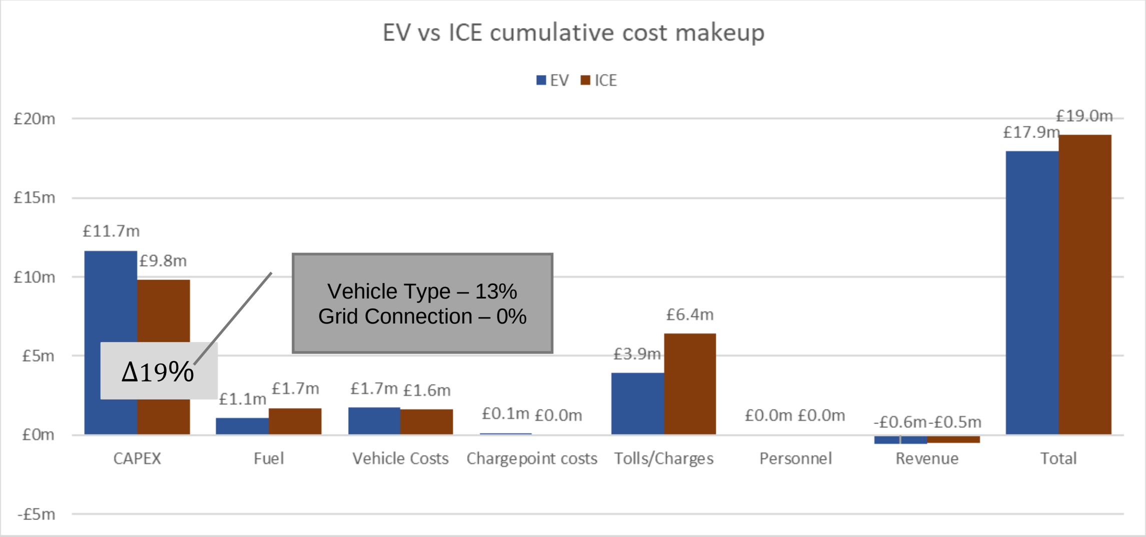


Figure 8 – Premier Park – Fleet cost breakdown based on mix of Partner/ePartner and Expert/eExpert – Base case

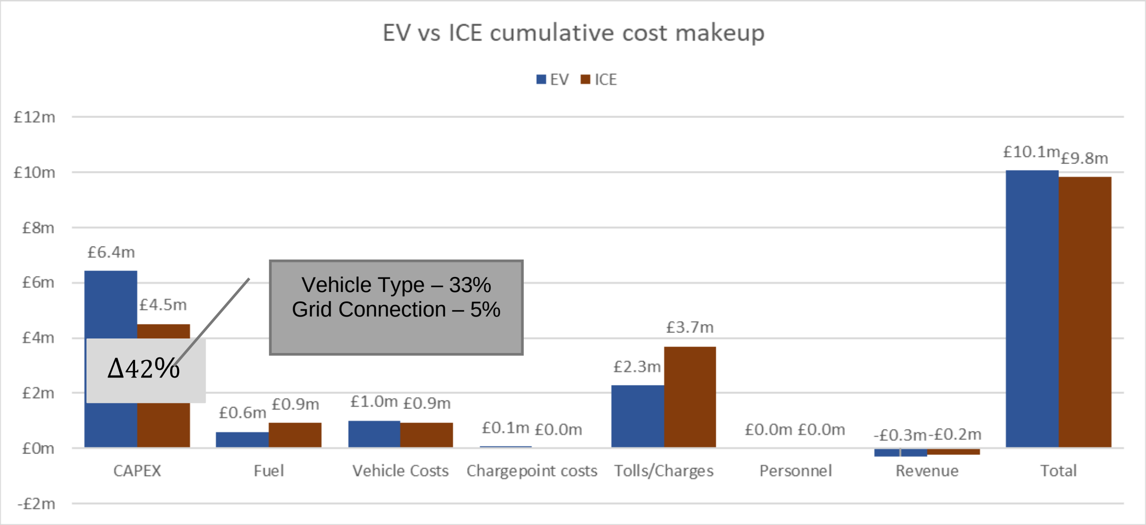
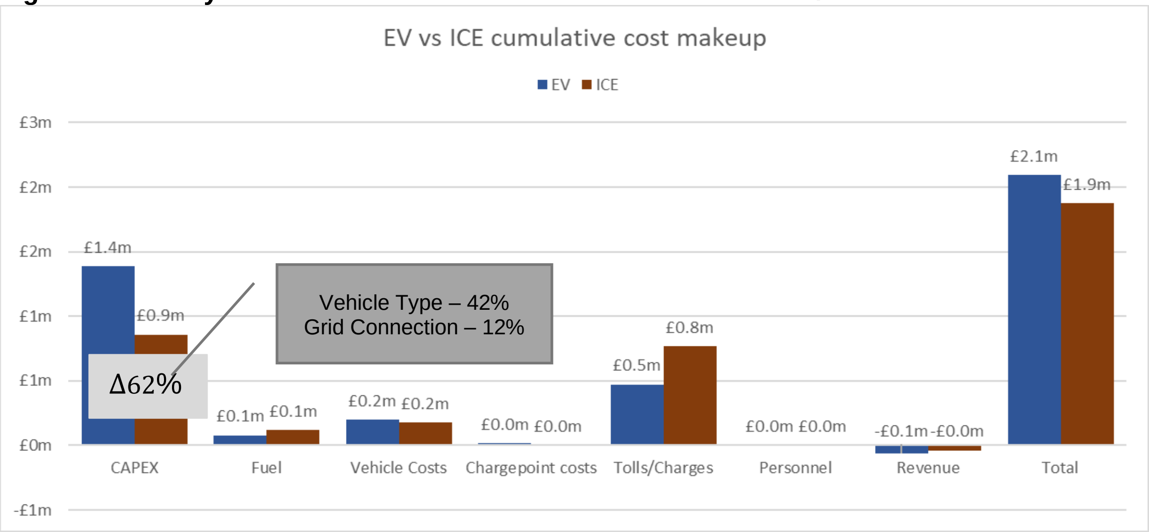
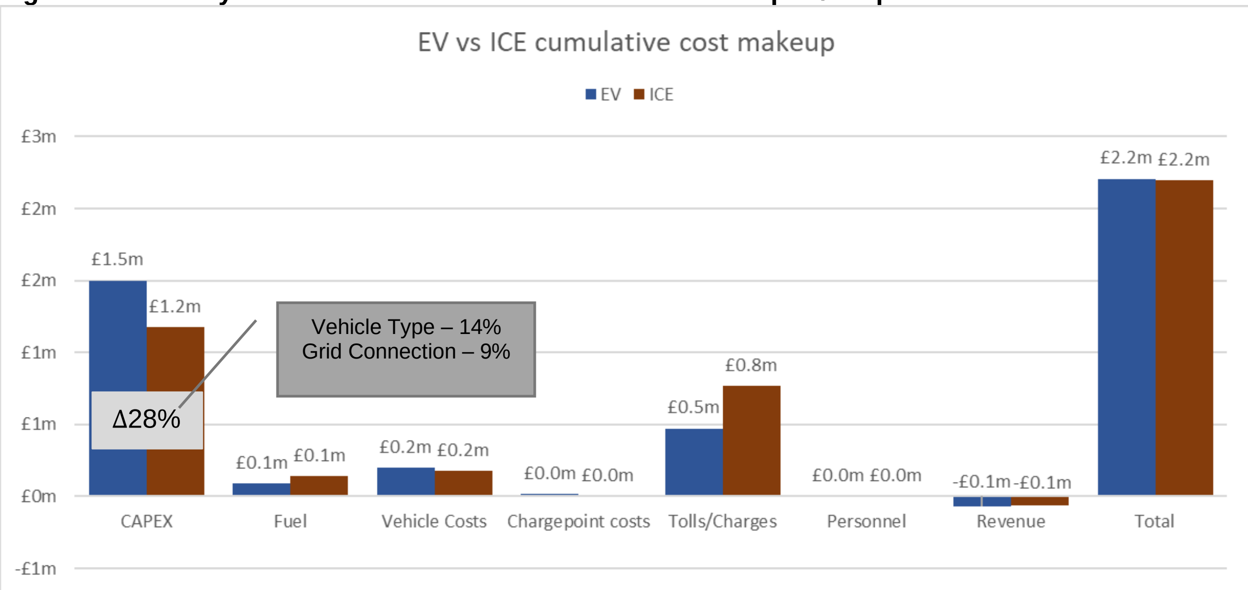


Figure 9 – Bexleyheath – Fleet cost breakdown based on Partner/ePartner – Base case



For Bexleyheath, results shift considerably if Expert/eExpert are assumed instead of the Partner/ePartner combination, as shown in Figure 10. The difference in CAPEX is now reduced from 62% to 28% while the TCO over eight years is at parity. Although in this scenario, vehicle purchase price difference still accounts for half of the overall CAPEX difference (14% out of 28%), the network connection cost becomes a significant factor that is driving higher CAPEX for the EV fleet. This will be investigated further in the next section.

Figure 10 – Bexleyheath – Fleet cost breakdown based on Expert/eExpert – Base case



3.2.4.3 Connection cost

Another major impact on CAPEX cost for EVs is the electricity distribution network connection cost. Due to Mount Pleasant being historically a large commercial site the existing ASC was sufficient and the depot did not require reinforcement even with base case scenario of the whole fleet. This is not the case for Bexleyheath and Premier Park. CAPEX of both sites is considerably higher due to cost of connection upgrades (Table 14). The connection cost estimates were calculated by UK Power Networks based on each depot's expected load, location and existing ASC.

If Smart Charging was implemented across Premier Park and Bexleyheath depots, in order to reduce peak load from EVs, Table 14 shows that no reinforcement would be necessary for full fleet electrification. Despite no reinforcement costs, a 100% EV fleet would still be more expensive than 100% ICEV fleet, at these depots, the difference in costs is considerably smaller than in the base case. When all the depots in the study are combined, base case total costs for all depots with 100% EV fleet is £513,400 cheaper than ICEV fleet, while with smart charging this amount increases to £959,400. Network connection costs could make some business cases negative.

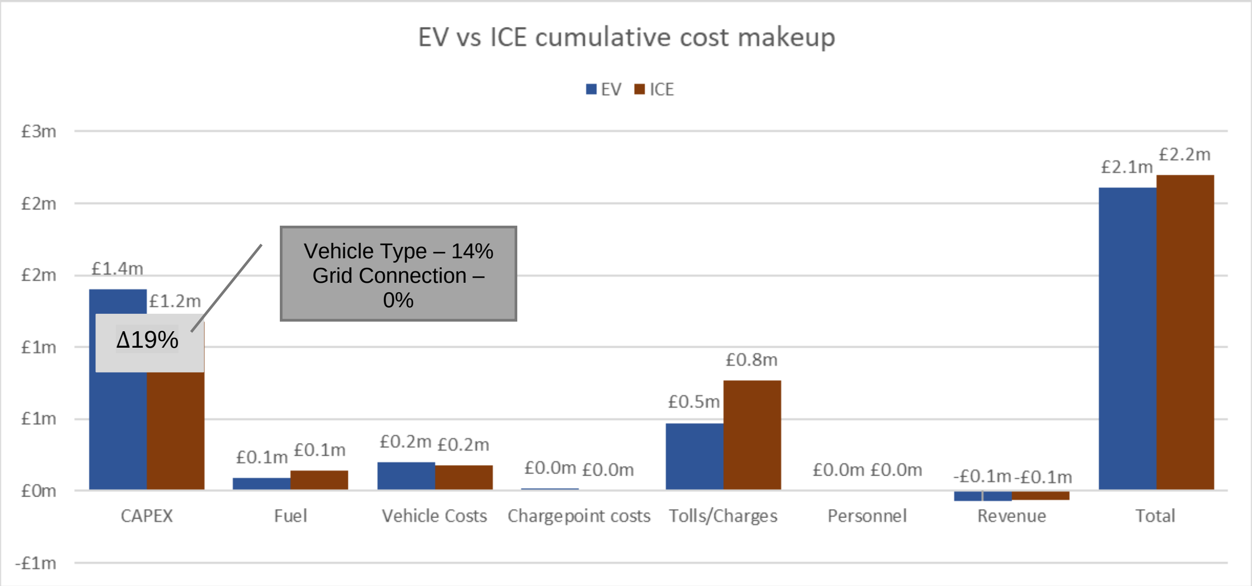
When considering a specific depot however, network connection costs are very much dependent on location and the current available capacity. If the Mount Pleasant full EV fleet of 192 vehicles were to be introduced to Bexleyheath (a small depot with 23 vehicles), which currently has a small connection, then network connection cost could be in the region of £1m as significant upgrades would be required. If that was to be the case, then network connection cost would have a significant impact on the overall cost of fleet electrification.

Eliminating the need for network reinforcement would not only save money but also reduce the timeline required for the fleet electrification. As examined in section 3.6.3.2 of Deliverable D4, the timescale for reinforcement in base case scenario could take up to 12 months.

Figure 11 shows Bexleyheath fleet electrification based on Expert/eExpert vehicle type with smart charging. In this case the eight year EV Fleet TCO would be lower than ICEV.

Using smart charging to limit peak loads, and in doing so reduce or avoid connection upgrade costs, can have a significant role in the difference between cumulative cost makeup between ICEV and EV fleet. Through profiled connections, and exploring the use of smart charging to manage load on the distribution network, Optimise Prime is establishing methods to reduce the upfront cost of connection for fleets. This analysis has shown that, while the cost of connection may be relatively small compared to other costs of electrification, it could be instrumental in the business case for investment in depot electrification.

Figure 11 – Bexleyheath – Fleet cost breakdown based on Expert/eExpert – Smart Charging



The cost and implementation time benefits of Profiled Connections will be discussed in D7. Profiled Connections (see section 3.6.4 of Deliverable D4) are a new type of connection being trialled by Optimise Prime, where both customers and DNOs can agree on the connection profile that can vary every 30 minutes across the day. This may reduce reinforcement needs for the customer, as the energy demand would be spread across the day, but would also take into consideration the network capacity and the energy required to satisfy the depot's operations. The smart optimisation system can also ensure that all vehicles have sufficient battery charge for the next shift while power usage fits under the ASC profile. More information on Profiled Connection Methodology and Trials can be found in Section 4.1.

3.2.4.4 Congestion charges

Additional charges which apply only to ICEVs can be a significant driver for the difference in operational costs. The Royal Mail trials fleets are in the London area and a significant number of the vehicles are required to pay daily congestion charges. However, while charges for the EV fleet are smaller than for the ICEV fleet, the difference reduces after the end of exemption period for EVs in October 2025. This change of policy has a significant impact on the economics of the EV fleet.

For Mount Pleasant, if the congestion charge exception was extended for EVs across the whole eight year period, the Cumulative Net Saving after eight years would increase from 6% to 26%. The eight year Cumulative Net Saving would also improve in medium and small depots. These figures are based on the 'base' case scenario. Congestion pricing is location specific and not within the control of fleet managers, unlike other elements of the TCO such as vehicle procurement, time of charging (to avoid network connection costs or at low electricity costs) and installing LCTs.

Not every fleet will be impacted by congestion charges, but being aware that those charges have an impact on the EV fleet OPEX, might give a voice to those lobbying against imposing congestion charges for EVs.

Ultra-low emission zone charges have not been considered, given that the alternative ICEVs are Euro6 compliant and would not be subject to such charges at the time of writing.

3.2.4.5 CO_2 emissions

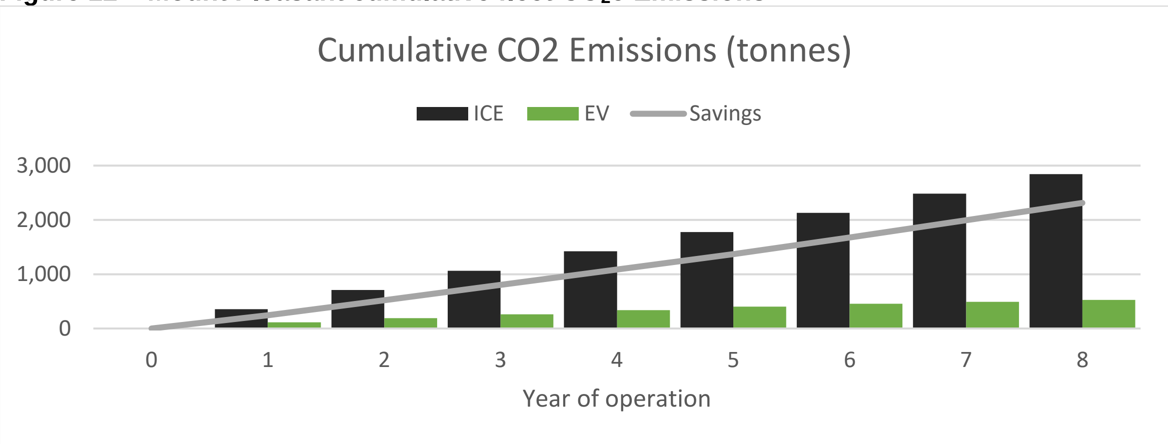
The project has assessed what carbon dioxide equivalent (CO_2e) savings can be achieved by accelerating the electrification of commercial fleets.

The Royal Mail trials produce on average 80% less CO_2e compared to the ICEV fleet. The results show the CO_2e reduction in operations regardless of the size of the depot.

For Mount Pleasant, the eight year cumulative CO_2e emissions for the ICEV fleet is 2,841 tonnes of CO_2e, which would require the equivalent of 135,285 trees[15] to absorb the CO_2e in comparison to 25,142 trees needed to sequester the CO_2e emissions of the EV fleet. For a considerably smaller fleet, at Bexleyheath, there would be 9,238 trees needed to sequester the CO_2 produced by the ICEV Fleet compared to 1,857 trees needed for EV fleet CO_2 emissions.

Figures 12, 13 and 14 illustrate the calculated CO_2e savings at the large, medium and small depots.

Figure 12 – Mount Pleasant cumulative fleet CO_2e Emissions



[15] Based on a fully grown tree which can absorb up to 21kg of CO_2 per year

Figure 13 – Premier Park cumulative fleet CO_2e emissions

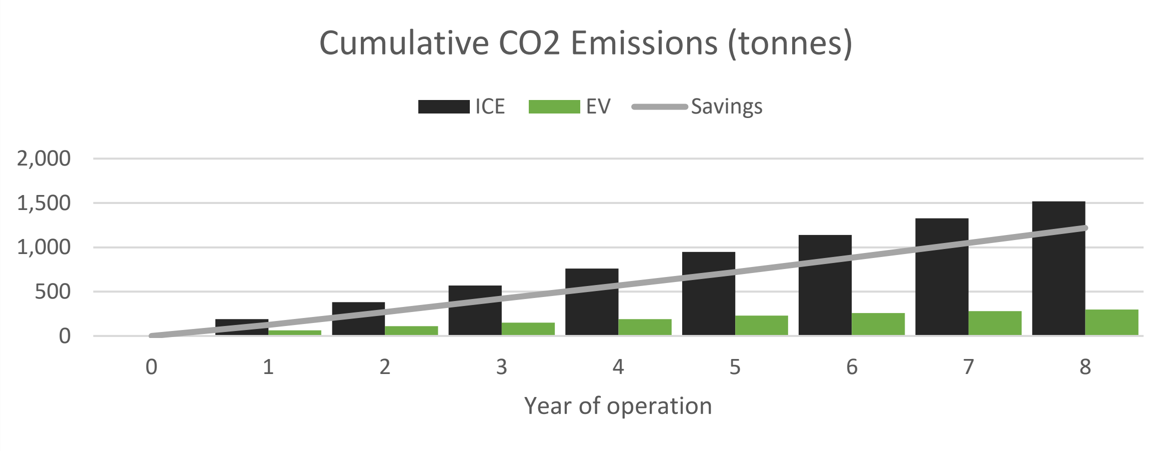
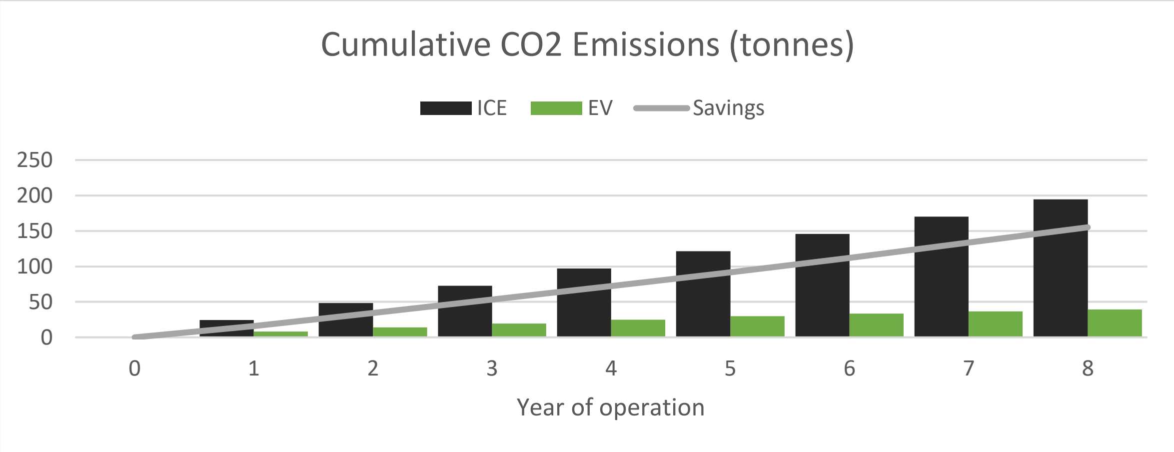


Figure 14 – Bexleyheath cumulative fleet CO_2e emissions



3.2.4.6 Base case Vs. Smart Charging with ToU Tariff

Smart Charging, in conjunction with cost minimisation against a ToU tariff, will be investigated against the base case. As previous findings show, smart charging could considerably reduce the overall CAPEX costs of network connections for a EV fleet. Optimising charging against a ToU tariff will show how much further OPEX costs can be reduced for an electrified fleet.

Early simulations, performed in November 2020 for Mount Pleasant, indicated that by shifting load in a cost minimisation scenario, from the more expensive to cheapest times in Royal Mail's ToU Tariff, the cost of charging could potentially be reduced by as much as 65%. Applying this saving to the charging cost calculated in the current TCO, would reduce the OPEX by £685,860 over eight years and improve TCO by 3% in Cumulative Net Saving from 6% to 9%.

Trials of smart charging with ToU cost minimisation are ongoing to gauge how much load can be shifted and to consider the impact of overlaying time of use tariffs with provision of flexibility services and profiled connections.

3.2.4.7 Flexibility

Through the testing of flexibility services across the Royal Mail depots, Optimise Prime is exploring the practicality of using commercial vehicle depots to provide demand turn down to a DNO in response to a request. Provision of such flexibility services could potentially have a positive impact on OPEX for the EV fleet as payments will be received for availability and/or provision of services.

The project has created three energy flexibility products (Products A, B and C), (see Deliverable D3 for detail) of which Products A and B are being tested at the Royal Mail depots. The intraday product, Product C is being tested in the home trials (and not being tested with Royal Mail as the complexity of bidding and dispatching would likely outweigh the benefits on non-aggregated depot loads). The main difference between Products A and B is procurement/timescale and dispatch process. In Product A, capacity is procured by tender, a month ahead and dispatched in real time when needed by the DNO. Product B is tendered for and dispatched as a day ahead schedule. Product A is paid for based on availability and utilisation, while for Product B is paid for based on utilisation.

Flexibility trials are ongoing and the value of flexibility will be considered in the final report. There are a number of questions that the project is currently seeking to answer that will determine the value of flexibility to a fleet:

- Whether a day ahead or longer-term product is more appropriate for commercial fleet flexibility. While the project has found EV schedules to be broadly predictable, the availability of vehicles cannot be fully controlled. A number of factors, such as schedule changes, workload and seasonal changes in EV efficiency need to be taken into account in making flexibility offers
- The ability of EV fleets to provide point-in-time demand reductions on request, vs making their demand follow a day long schedule
- The comparative benefits of products with or without availability payments, given the likelihood and magnitude of flexibility calls
- The potential revenue from flexibility. Due to the lack of a market within the trials, consideration will be given to the benchmark prices in other flexibility markets – for example a benchmark price of £549/MWh was calculated based on the data published by Piclo (a flexibility bidding platform) with confirmed bids between 2021 and 2027 that were accepted by UK Power Networks.
- The potential cost of providing flexibility services, and how this scales up with depot size/volume of flexibility available

Although the real value of flexibility remains unknown, obtaining additional revenue through the provision of flexibility services may be an attractive option to offset increases in electricity costs. However, offering flexibility is not without cost for the participant, either directly through the systems and processes needed to bid and dispatch, through the impact on operational flexibility, or in the form of the opportunity costs of not missing out on charging at a lower electricity price. The project's analysis of the economic benefits of flexibility services for the fleet will be explored in Deliverable D7 following the trials.

3.2.4.8 Low Carbon Technologies (LCTs)

While the trial of LCTs is outside the scope of Optimise Prime, it is clear that technologies such as distributed renewable generation can play an important part of the business case for a depot. While some Royal Mail depots do have solar panels installed, the data on generation was not available to the project, so estimates have been made based on the solar panels installed at the Islington depot.

According to the Google satellite view, Islington depot has 62 roof-top solar panels installed. Following assumptions of average rooftop solar panel power and Hitachi market knowledge of the price and installation cost per kWp, calculations show that investment could be on average £21,600 and panels would be able to generate 24,300 kWh per year.

If power generated would be consumed by the depot, based on the current tariff of £0.23/kWh, the total saving in year one would equal £5,589. This saving would represent 29% of the electricity costs for charging the fleet at the Islington depot. The return on investment would be after four years of installation and given the average of 25 years solar panel lifetime, this could be an option for electric commercial fleets based at locations that can use the solar power at the time of generation. The Royal Mail fleet shows significant variation between depots as to whether EV charging is taking place in the daytime, when solar generation is highest.

If the energy generated was to cover 29% of the electric fleet energy requirement, considering increasing energy prices, this could reduce the impact of future price increases on fleet electrification. If energy prices were to increase again by 50%, then the return on investment would be in less than three years for Islington. With solar panels added, the eight year NPV improves at Islington depot by £16,329. Although those calculations are based on benchmarked inputs, they still present high potential returns for LCTs and their positive impact on the TCO for EV Fleets.

3.2.5 Key Learnings and next steps

This section provides an interim update on the work that Optimise Prime is doing to model the business case for electrification of depot based fleets. The project has been fortunate to have been conducting the TCO analysis during a period of high volatility for a number of key value drivers for fleets. This has enabled Optimise Prime to highlight the main factors that influence the fleet TCO and that are currently driving EV affordability. The main conclusions from the analysis so far are summarised below:

At present, whether TCO favours EV or ICEV fleets varies by depot, driven largely by EV type and cost of connection

The difference between EV and ICEV TCOs is not significant and there are a number of OPEX and CAPEX items that can make or break the investment case.

Energy price rises have had some impact on the TCO for depot based electric fleets, impacting the investment case by around 1%

Electricity prices have increased recently by around 50%, while diesel and petrol price rises have been around 15% year-on-year. Control over electricity prices through agreed corporate tariffs covering the depots has limited impact of price rises. Future movements in commodity prices could continue to impact the overall investment case unless coupled with other changes such as vehicle cost reductions.

The OPEX savings for EVs even without smart charging can offset a 28% higher price of EVs vs ICEVs at present

While cost parity between EVs and ICEVs is predicted, that point is still some way off. Supply constraints, caused by the semiconductor shortage, more aggressive targets for the end of ICEV sales and other commercial factors have especially impacted the LCV market, preventing a reduction in EV prices. OPEX benefits of EVs can offset a higher CAPEX cost, but at present many EVs are still too highly priced relative to ICEV alternatives.

Connection costs are normally a relatively small proportion of the overall fleet electrification costs, but given the small difference in TCO could impact investment decisions

Using smart charging to alleviate the need for connection upgrades has been shown to produce benefits in the Royal Mail case. However, the variability in cost of connection between sites can be significant and so it is difficult to generalise the extent to which connection charges impact TCO.

Congestion Charging can provide benefits to EV TCOs, but these benefits are limited by time and location

Within London, the cost of Congestion Charge for ICEV fleets can be significant. However, the current exemption for EVs is planned to end in 2025 limiting its impact on long term TCOs. Other measures penalising ICEV use in London and other areas may be introduced in the future, but the impact of such measures on TCO cannot be predicted. Fleet managers also have little control over Congestion Charges, as delivery fleets like Royal Mail have no option but to enter the zone to make deliveries.

Many of these cost factors are variable and will continue to change due to external, often global, market forces. The application of government tolls, charges, bans and policy incentives will tend to favour EVs over ICEs for some time to come and it is expected that the continued deployment of renewable energy may ultimately bring the cost of electricity down.

Furthermore, the analysis also looked at factors that provide a more predictable and durable benefit over the period in question such as the CAPEX and OPEX reductions that smart charging, profiled connections, tariff optimisation and energy flexibility can provide to EV fleets. These factors can be implemented by fleet owners independent of market forces, and together with supplementary schemes such as the roll-out of LCTs could help organisations achieve a positive TCO compared to ICEV in addition to environmental benefits. Based on findings from the trials these factors will be explored further in the project’s final deliverable.

3.3 *Total Cost of Ownership for home-based fleets – an example from Centrica*

3.3.1 Introduction

The Centrica TCO aims to model the total costs of owning and operating Centrica's large fleet of British Gas vans, comparing the costs assumed by the business for their diesel and their electric vans. This TCO model forecasts the potential economic effects of electrification at a whole-fleet level and a single vehicle level. The TCO illustrates the key levers that influence the total costs for both the ICEV and EV fleet, showing what factors need to be monitored closely to ensure businesses with similar fleets can transition in a cost-effective manner.

For British Gas's fleet, every engineer is provided with a personal van that they take home each day. Their fleet has the following general characteristics:

3.3.1.1 The fleet

The British Gas fleet is composed of ~9500 medium-sized panel vans. The diesel vehicle model used in this analysis is a Vauxhall Vivaro and its zero-emission alternative the Vauxhall Vivaro-e, which is their current electric van of choice. Centrica typically lease their vehicles for six years at a time. However, to try to maximise the applicable value of the modelling work Optimise Prime decided to investigate a short lease-fleet (five year) and a longer lease fleet (eight year). In the context of Centrica's assessment, the five year would be the most valid. It was hoped that analysing two polarised TCO views would yield the most generalisable learnings.

3.3.1.2 Mileage

Due to the nature of British Gas' work, each van travels long distances completing work at customers' homes. Based on mileages reported in the Optimise Prime Behavioural Surveys (see Section 3), an assumed average mileage per driver of 70 miles per day was used. This was deemed appropriate since although drivers commonly drive less than 70 miles, they can drive in excess of 120 miles in a day if they are on a call-out shift.

3.3.1.3 Congestion and Emissions Charges

Only ~2% of British Gas drivers operate in London within the Congestion Charging zone, which charges £15 per day to enter. An exemption applies for battery electric and hydrogen fuel cell vehicles, although this will cease in December 2025.

Though these ~2% will most likely also be passing through the London Ultra Low Emission Zone (ULEZ), this had no relative impact on their TCO calculations since the Euro 6.2 diesel engines they use in the Vauxhall Vivaros also remain exempt from this charge.

Table 18 – The main inputs and assumptions for Centrica's TCO

Input Type	Input Name	Input Value
Whole-fleet Inputs	Fleet size	9,500 vehicles
	Mileage	70 miles per day
	Total working days assumption	251 days per year
	Assumed number call-out days	12 per year
	Assumed % fleet entering London congestion zone / ULEZ zone	2%
	Vehicle lease price	See Table 23
	Vehicle maintenance cost	£0.04 per mile

Input Type	Input Name	Input Value
Diesel Vehicle Inputs *-Vauxhall Vivaro*	Vehicle engine efficiency	0.09 litres / mile
	Vehicle AdBlue spend	£0.005 per mile
	Vehicle emissions standard	Euro 6.2
	Vehicle annual tax cost	£140
	Vehicle insurance cost assumption*	~£740
EV Inputs *-Vauxhall Vivaro-e*	Vehicle lease price	See Table 23
	Vehicle maintenance cost	£0.03 per mile
	Vehicle power efficiency	2.5 miles / kWh
	Vehicle annual tax spend	£0
	Vehicle insurance cost assumption*	~£740
Emissions Assumptions	Diesel CO_2 emissions	2.62 kg CO_2 /litre of diesel
	Electricity CO_2 emissions	Operational Emissions model**

*Assumed no insurance price difference for EV vs ICEV.
** Optimise Prime have developed a separate model which calculates the approximate carbon emissions per kWh taking into account to gradual decarbonisation of the electricity network.

3.3.1.4 *Centrica's Charging Strategy*

Since each driver has their own vehicle and takes it home with them each night, Centrica pursue a home-based charging strategy encouraging drivers to plug-in once they are home on a personal CP. This strategy could allow Centrica to capitalise on lower overall electricity costs associated with home tariffs compared with the higher prices at public charging stations. However, Centrica take full responsibility for procuring, installing and maintaining each personal CP for the driver, which results in additional CAPEX and OPEX for the business. These costs are summarised in the following table:

Table 19 – Summary of CP costs for Centrica's home-charging fleet

Cost Type	Cost Name	Price (£)
CAPEX (purchase and installation)	Home CP (3.5 to 7 kW)	620
	Installation	325
	OZEV CP installation grant*	-325
OPEX (maintenance, ancillary costs and licenses)	CP failure cost**	350
	Control software	12 (per socket p/y)
	Reimbursement software	72 (per socket p/y)
	Ancillary costs (replacement of leads)	7.5 (per socket p/y)

*As will be discussed later in the report, the OZEV grant is no longer available for fleets like Centrica installing CPs at home. This cost was used in the frequent comparisons between the 2021 scenario for Centrica, and the current (2022) scenario.
** The reported approximated failure rate for CPs was 1%.

To achieve the maximum economic benefits of a home-charging strategy, drivers would need to enrol on a time of use tariff and optimise their charging schedule so that their van is charging mostly on cheaper night-time tariffs and avoiding pricier day-time tariffs, particularly during peak hours of between 1700 and 2000 hours. Smart charging can yield significant TCO savings when compared to those charging on an unmanaged charging schedule.

Though home-charging is the primary strategy for Centrica, it is not always possible to install a CP at a driver's home. This is discussed further in section 2.1.6, and it can be as a result of various physical or technical constraints. For example, they may not have a drive, their drive may not be near their house, or it is not technically possible to install an EV charger. If a British Gas engineer is unable to install a home-CP, their only option is to charge using public charging infrastructure. As a result, these drivers find local public charging infrastructure near their house – usually slow CPs from lampposts or in community charging locations – or they must charge on-shift, or on their way home at commercial charging stations. This results in higher costs of electricity, and therefore a less favourable EV TCO.

3.3.1.5 Timing: the 2021 vs 2022 scenarios

As part of the modelling exercise, it became evident that comparing the economic environment for electrification, in 2021, against 2022, could provide useful outputs. Since Optimise Prime has started, the commercial environment for fleet electrification has changed. In addition to the impacts of the COVID-19 pandemic, electric LCV prices have not reduced sufficiently to bridge the gap with ICEVs owing to ongoing supply constraint and other commercial factors, perhaps driven by the approaching ban on ICEV's in the UK in 2030. Furthermore, with the markedly higher energy and fuel prices, as well as the termination of OZEV grants which previously provided a financial contribution to businesses installing CPs, it has become harder to reach TCO parity with ICEVs since 2021.

A final consideration to note in the modelling of the 2022 scenario there is also a decreased financial benefit of the congestion charging zone exemption for EVs as there is one less year of benefit until EVs start being charged in 2025. The project analysed the impact of these changes in Section 3.3.1.4 by building assessments of both the 2021 and 2022 scenario.

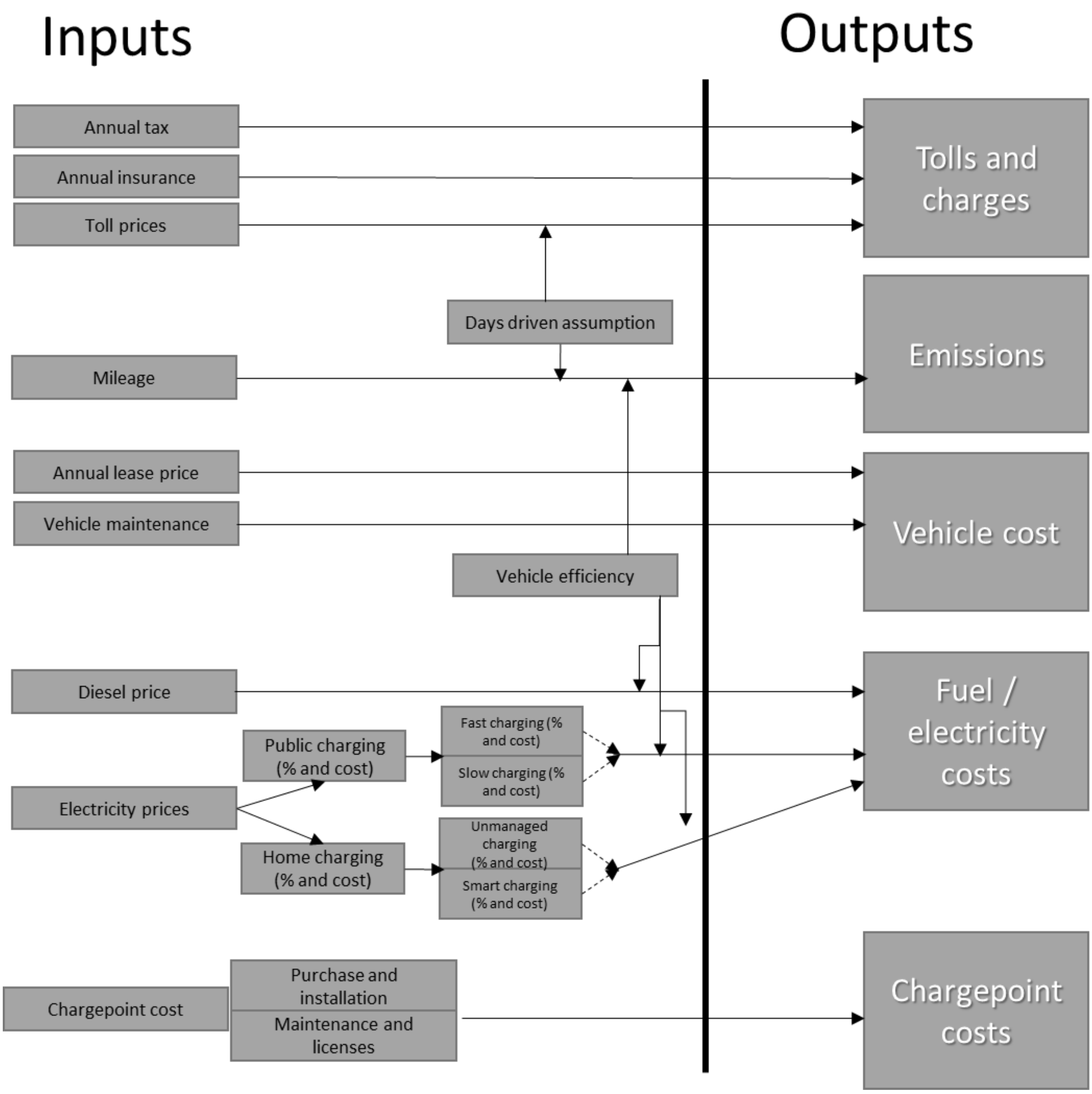
3.3.1.6 Model Overview

The TCO business model created as part of the Optimise Prime project is formed of:

- The lease price and annual maintenance costs of the ICEVs and EVs.
- The fuel and electricity costs to power the vans according to vehicle efficiencies and mileages, as well as the diesel price per litre and electricity prices per kWh.
- Associated running costs covering annual insurance, tolls and tax payments.
- Cost of purchase, installation, and maintenance of home charging points for EVs, as well as all necessary licenses.

These inputs and the outputs that are generated are summarised in Figure 15.

Figure 15 – Main inputs and outputs for Centrica TCO assessment



Given there is a mix of drivers who are able to charge at home and those that must charge using public infrastructure, the model was designed to cater for multiple scenarios in which the percentage blend of the fleet using these two forms of charging could be adjusted. Public and home charging both carry very different costs, with the latter composed of lower overall electricity costs. However, additional CP expenses which the former avoids but suffers from the higher price per kWh. Therefore, the percentage of the fleet charging in each way will affect the total cost of operating the fleet.

Each charging method contained subsets within them. Public charging could mean the vehicle was charging at a local, 'Slow/Fast' CP with a lower price per kWh, or it could mean the vehicle is charging at commercial 'rapid' charging stations which charge higher rates per kWh. Generally, Centrica expect ~35% of their total fleet once fully electrified to be charging at public CP. Of that 35% charging publicly, they expect 65% to be charging at 'Slow/Fast' CP with the remainder charging at 'Rapid/Ultra-rapid' CP (see Table 20).

Table 20 – Proportions of charging methods across the Centrica fleet for the Baseline case

Charging type	Percentage	Type of Charging Type	Percentage
Public Charging	35%	Rapid Charging	35%
		Slow Charging	65%
Home Charging	65%	Smart Charging	10%
		Unmanaged Charging	90%

The home-charging vehicles, could either be on time-of-use tariffs capitalising on lower off-peak energy prices by charging their vehicle then, or they could be on a regular fixed tariff charging their van at expensive, peak-hours. Currently, approximately 10% of the home-charging British Gas vehicles are on the required time-of-use tariffs to enable charging optimisation (Table 20). However, Centrica hope to increase this as smart charging can significantly reduce their electric TCO.

Table 21 summarises the varied electricity prices that could be paid under the different scenarios outlined above, and Table 22 outlines the assumptions used to model smart and unmanaged charging.

Table 21 – Varying electricity prices for Centrica's TCO assessments

Year	Charging Type	Cost Name	Price (£/ kWh)
2021	Public Charging	Rapid Charging	0.42
		Slow Charging	0.13
	Home Charging	Assumed day-tariff	0.17
		Assumed night tariff	0.09
2022	Public	Rapid Charging	0.50
		Slow Charging	0.29
	Home	Assumed day-tariff	0.37
		Assumed night tariff	0.21

Table 22 – Smart vs unmanaged charging assumptions

Year	Charging assumptions
Smart charging	80% of charging assumed to be on the night-tariff
	20% of charging assumed to be on the day-tariff
Unmanaged charging	20% of charging assumed to be on the night-tariff
	80% of charging assumed to be on the day-tariff

3.3.1 Results

3.3.1.1 Baseline Case

This section analyses the results of the model to produce outputs that compare the TCO for an EV fleet compared to an ICEV fleet. The vehicle cost assumptions in Table 23 and the division of charging in Table 22 are obtained from discussions with Centrica.

Table 23 – Monthly lease prices for the vehicles

Fuel type	Year	Lease length	Lease costs
Electric	Vauxhall Vivaro-e	Eight Year	~£400 per month
		Five Year	~£535 per month
Diesel	Vauxhall Vivaro	Eight Year	~£219 per month
		Five Year	~£304 per month

3.3.1.2 Whole Fleet View Comparison

This section analyses the results of the model to compare the costs of an ICEV Fleet to an EV Fleet to understand how the costs compare.

These whole-fleet TCO comparisons were carried out for both the 2021 and 2022 scenarios.

3.3.1.2.1 Whole fleet view – 2021 scenario

Optimise Prime investigated a whole-fleet case, modelling an entire EV fleet of 9,500 Vauxhall Vivaro-e vans against an entire diesel fleet of 9,500 Vauxhall Vivaro vans.

The charging assumptions seen in Table 24 were used which were deemed to be the most realistic representation of their current charging system. The initial results showed the EV fleet to be far more expensive, for both the five year view (showing a net loss of ~£75m) and the eight year view (net loss of ~£70m). This loss is primarily formed from the gap in lease costs for the ICEV compared with the EV. At approximately £180 more expensive per month on an eight year lease and £230 more expensive per month on a five year lease, the monthly costs to lease the vehicle makes the overall EV TCO expensive. Multiplied across the fleet this results in over £140m of excess cost for EV, by far the factor generating the most expense for the EV TCO.

The cost savings from tolls and congestion zone are nearly completely offset by the costs to buy, install and maintain the CPs. Congestion Zone payments create £13.4m of net benefit for EV, but the total cost for the home CPs reaches £12.8m (Figure 16 to Figure 19).

Figure 16 – Cumulative fleet level net savings over eight years, EV vs ICEV, 2021

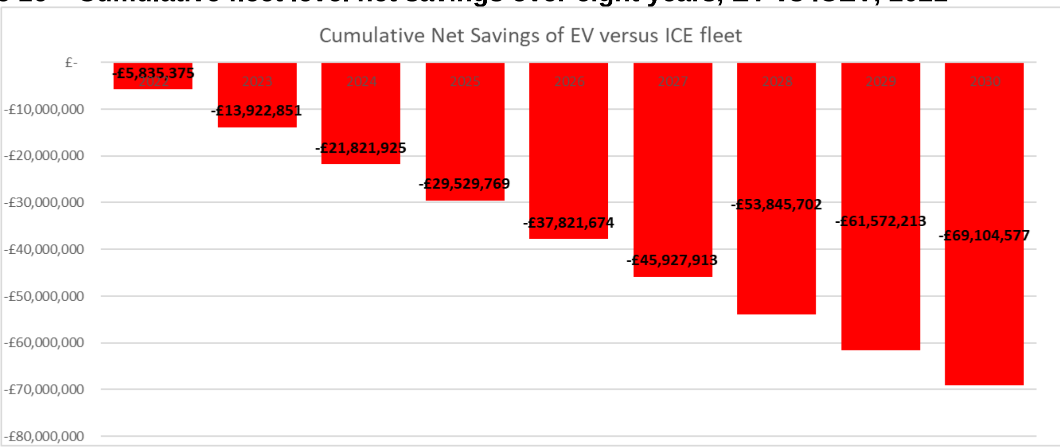


Figure 17 – Cumulative fleet level cost makeup over eight years, EV vs ICEV, 2021

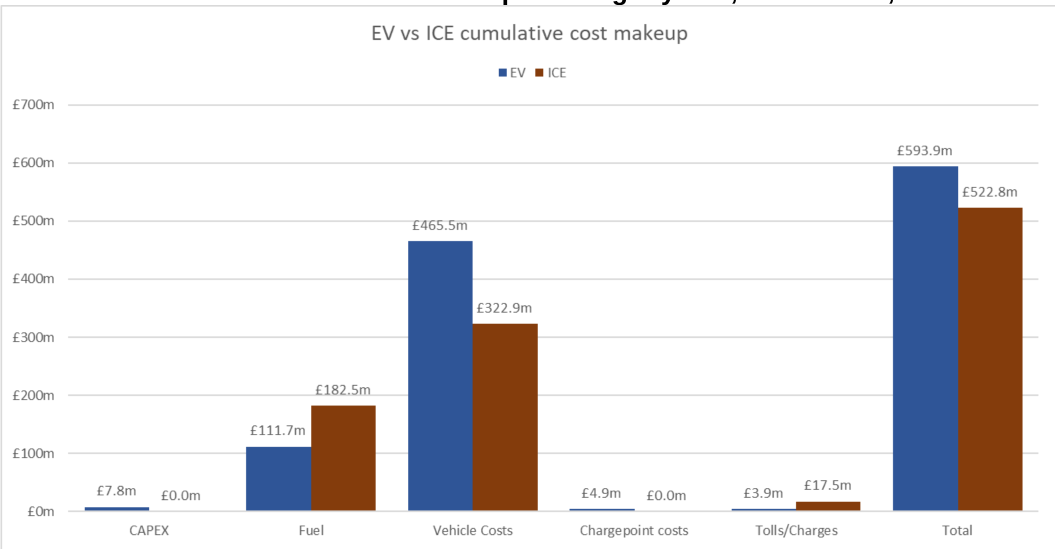


Figure 18 – Cumulative fleet level net savings over five years, EV vs ICEV, 2021

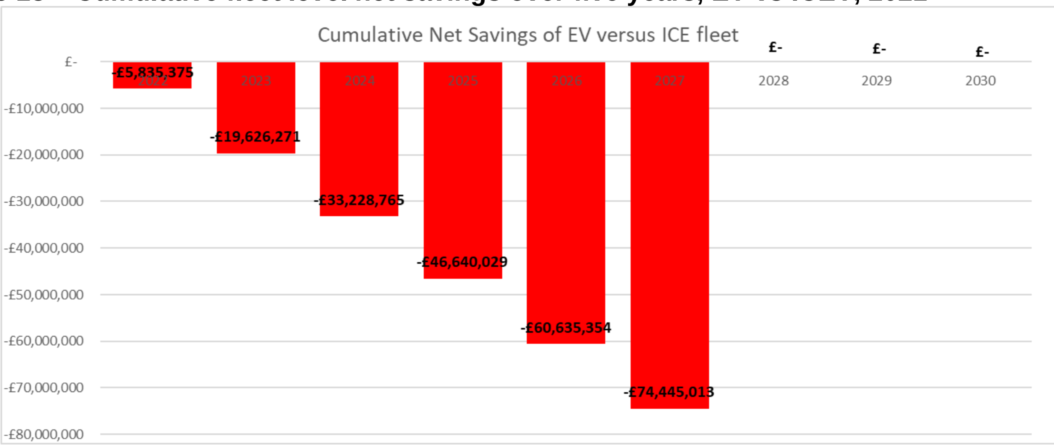
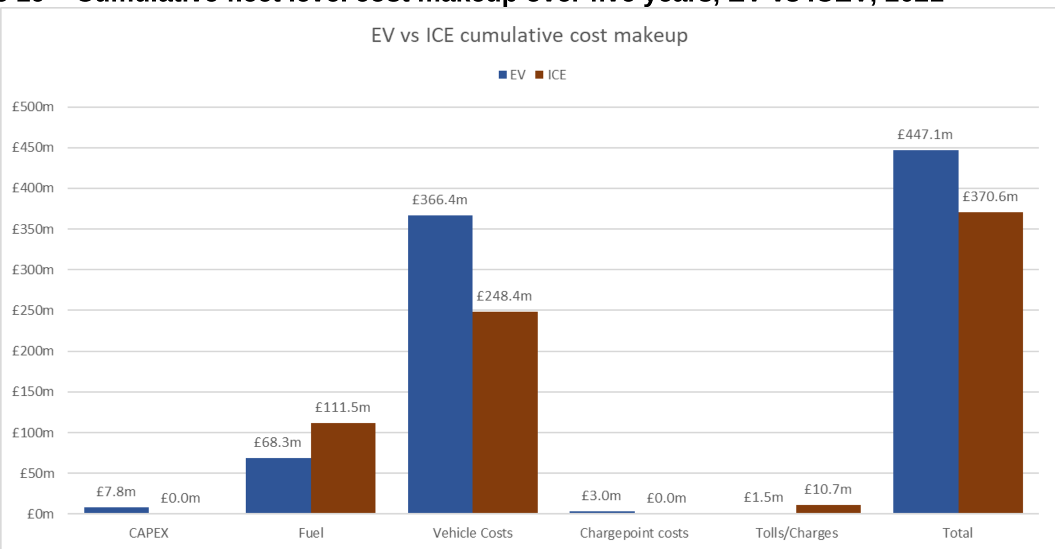


Figure 19 – Cumulative fleet level cost makeup over five years, EV vs ICEV, 2021



3.3.1.2.2 Whole Fleet View 2022

The results of the 2022 scenario demonstrate EVs as even less competitive with ICEVs one year on from 2021.

There is an increased cumulative net loss of ~£121m for eight years, shown in Figure 20, for EV against ICEV and a net loss of ~£107m over five years (Figure 22). The cumulative cost of an EV fleet, for 2022, totalled £668 million compared to £547 million for ICEVs over eight years (Figure 21). The reason for the large cumulative losses in 2022 of EV against ICEV is because there is a 44% increase in public charging cost and a 46% increase in home charging cost, as a result of changes in wholesale energy prices, whilst only a 13% increase in ICEV cost from 2021 to 2022. Also, the removal of the OZEV government subsidy of £325 for the installation of home CPs has been included (the subsidy will end in April 2022), which meant an increased cost of £2 million for the EV fleet.

Figure 20 – Cumulative fleet level net savings over eight years, EV vs ICEV, 2022

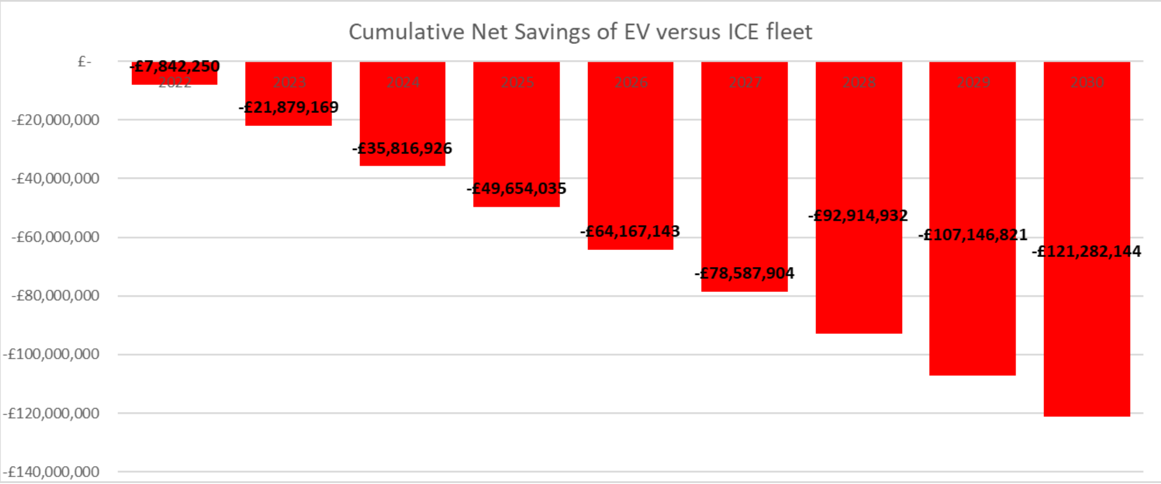


Figure 21 – Cumulative fleet level cost makeup over eight years, EV vs ICEV, 2022

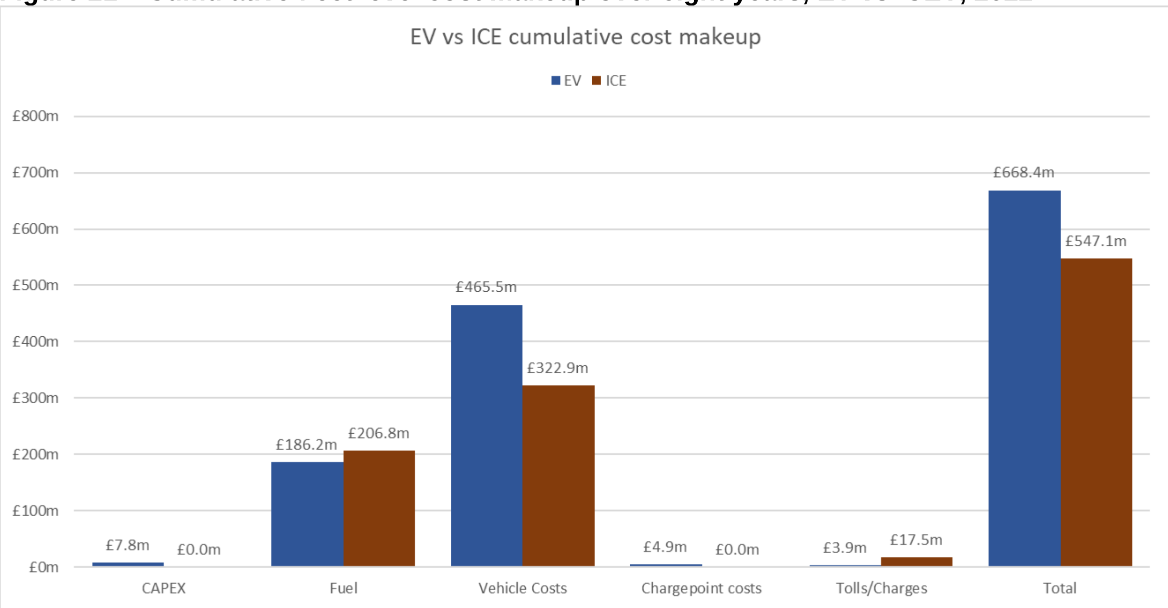


Figure 22 – Cumulative fleet level net savings over five years, EV vs ICEV, 2022

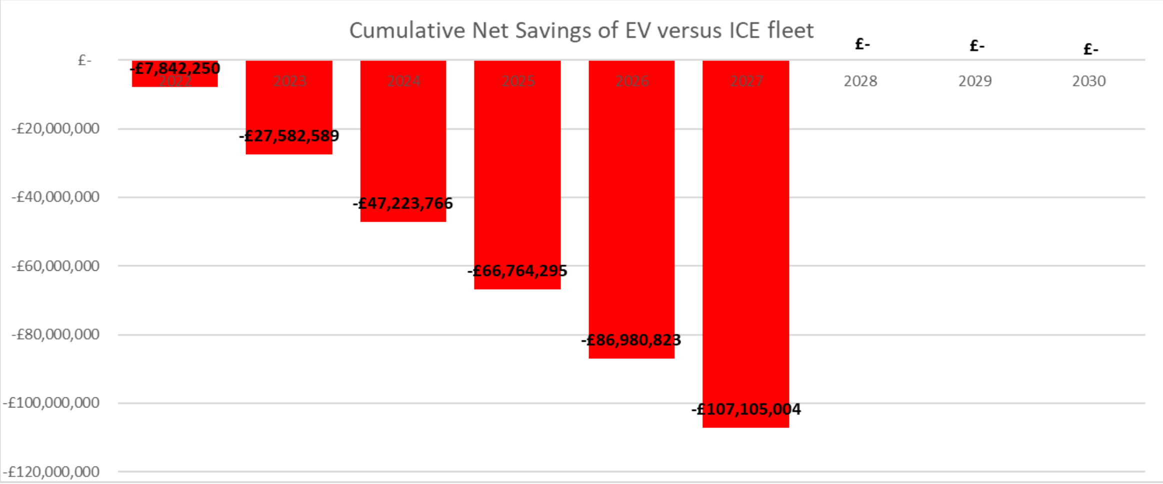
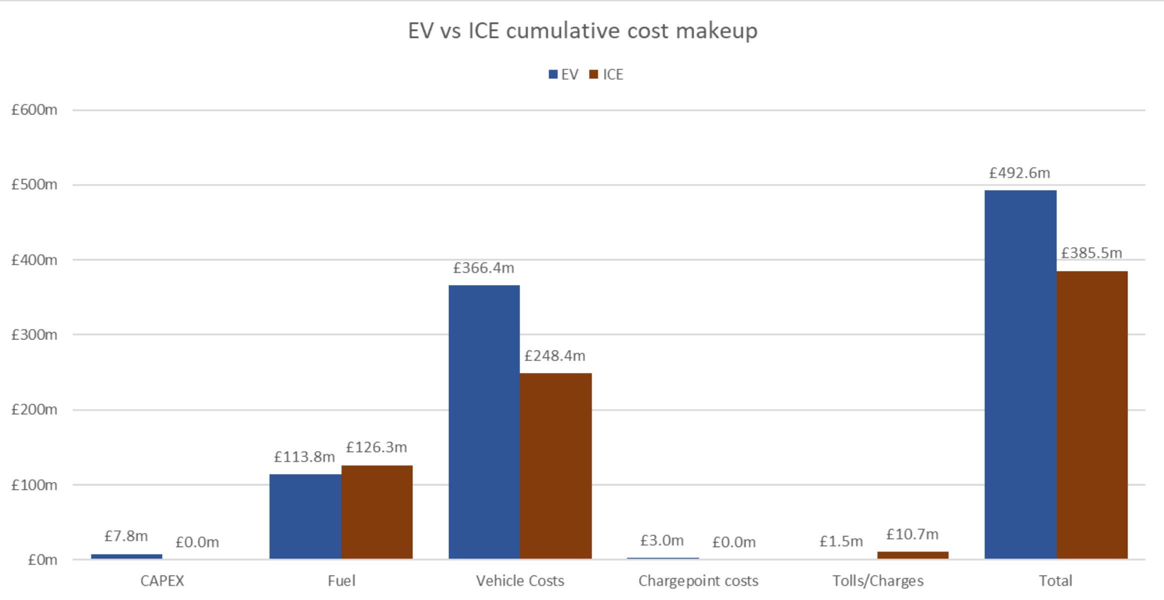


Figure 23 – Cumulative fleet level cost makeup over five years, EV vs ICEV, 2022



Whole fleet view conclusions

- In both the 2021 and 2022 scenarios, EVs work out more expensive than ICEVs. This is mostly resulting from large deltas in the monthly lease costs.
- Modelling the 2022 scenario has shown a significant negative change in the commercial environment for EVs. Considering the eight year view, the difference between the whole-fleet ICEV TCO and EV increases by ~£50m.
- Though EVs offers some financial benefits, such as lower running costs and advantages from reduced congestion zone payments, they are overshadowed by the differences in lease costs which currently prevents the EV fleet from reaching parity with an ICEV fleet. Importantly, some benefits from fuel and charge avoidance are offset by the costs to install and maintain the home charging points.

3.3.1.3 Single vehicle overview

As well as comparing TCO at a whole-fleet level, Optimise Prime assessed the TCO at a single van level. Through analysis on a single van scale, it was possible to get a more detailed understanding of how the three primary options for powering Centrica's fleet differed in terms of their impact on TCO: diesel, public charging and home charging.

The single vehicle comparisons were also completed for both the 2021 and 2022 scenarios. The TCO was run including and excluding the London Congestion zone charge.

In order that the average drivers' typical electricity costs were fairly represented, blended costs of electricity (per kWh) were created for both public charging and home charging. For public charging, this blended cost takes into account prices for both rapid and slow charging: for home charging, both smart and unmanaged charging schedules were blended.

3.3.1.4 2021 Home Charging vs Public Charging vs ICE

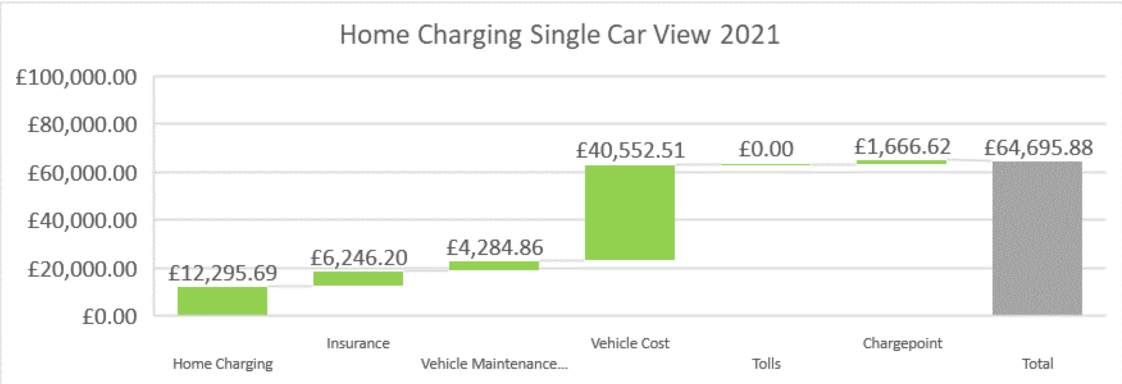
3.3.1.4.1 Vehicle Comparison 2021 (excluding London Congestion Zone)

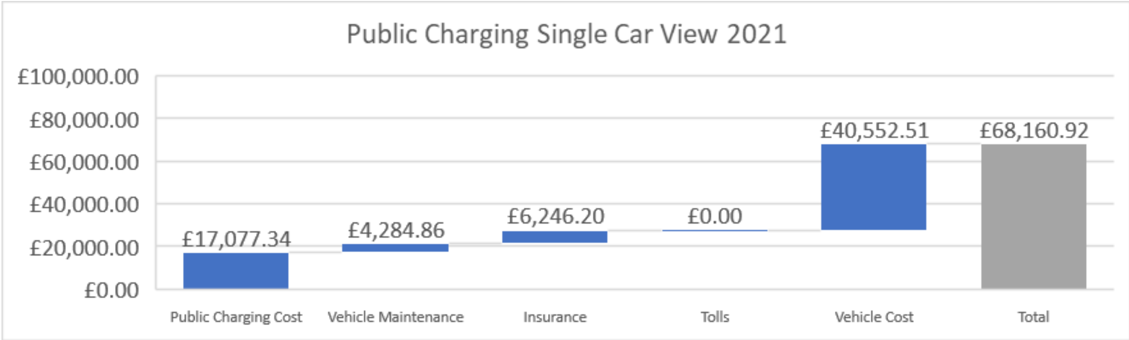
The majority of British Gas drivers (98%) operate outside the London Congestion zone, constituting 9,310 of the total 9,500 van fleet. The Centrica's fleet has little cost saving benefit to be gained from toll zones, particularly as the Euro 6 engines used in the Vauxhall Vivaro remain exempt from having to pay the ULEZ zone fee.

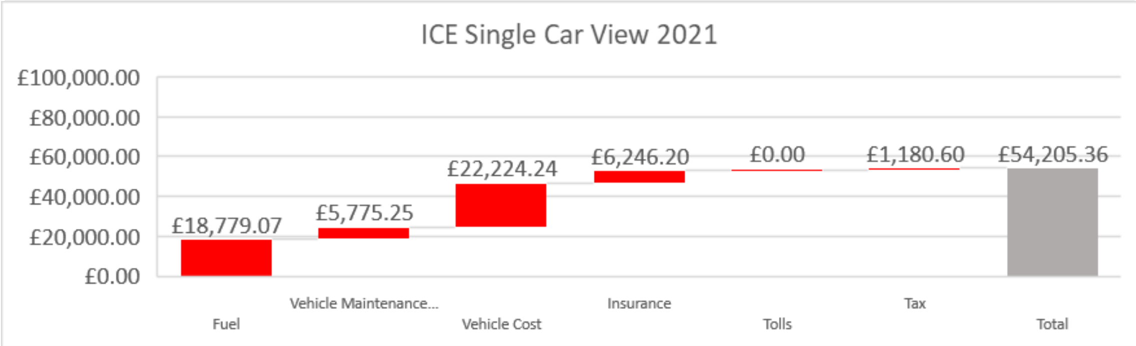
Home charging looked the more cost-effective charging strategy for Centrica by working out nearly £4k cheaper per van when compared with a public charging van. However, neither yielded cost savings when compared to the diesel van while the Congestion Charge was excluded.

Without the London Congestion Charge, diesel vans were ~£10k cheaper across an eight year lease and ~£9k cheaper across a five year period compared with home charging EVs. This difference widened with public charging where diesel vans would be ~£14k cheaper across an eight year lease and ~£12k net loss over five year.

Figure 24 – Single Vehicle TCO Comparisons – 2021 (eight year view, excluding London Congestion Zone)







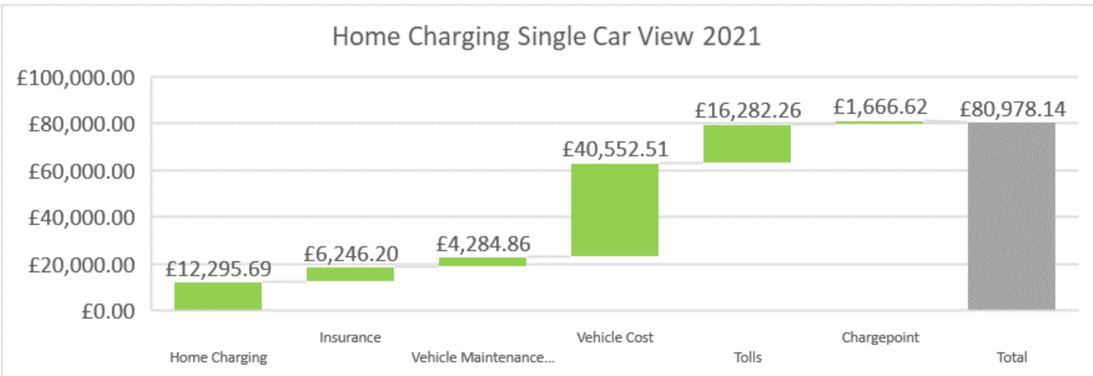
3.3.1.4.2 Single Vehicle Comparison – 2021 (eight year view, inc. London Congestion Charge)

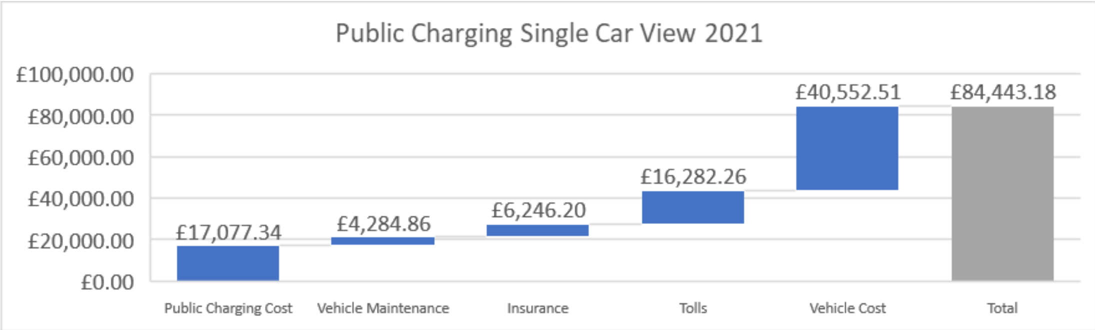
Approximately 190 British Gas drivers (2% of the total fleet) have to pay the Congestion Charge, which has a considerable impact on the TCO comparison.

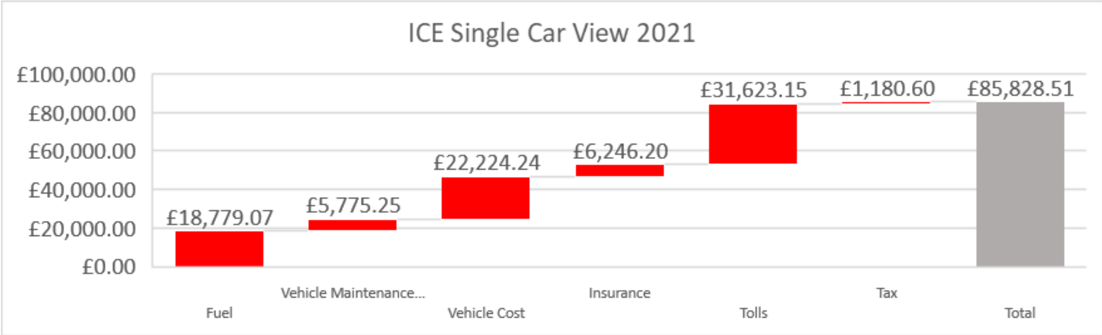
In 2021, with the London Congestion Charge included, there is a net saving of ~£5k per van across an eight year lease period and ~£6k per van across a five year lease period. The savings for a short lease period exceeding the savings made across a longer period reflect the fact that the real impact of the toll decreases as time progresses. So, for a five year view, the four full-years of cost benefit out of a total five year assessment make up a much larger proportion of the TCO than for an eight year view, where in four out of eight years the benefit occurs. In the eight year view, there is ~£5k savings for a home charging EV over ICE, as shown in Figure 25, whereas for a five year view this reaches ~£6k.

The public charging van was more expensive than the home charging van. Nevertheless, it was still cheaper overall than the ICE: a ~£1k saving per van across an eight year lease period and £4k over a five-year lease period.

Figure 25 – Single Vehicle TCO Comparisons – 2021 (including London Congestion Zone)







3.3.1.5 2022 Home vs Public charging vs ICE

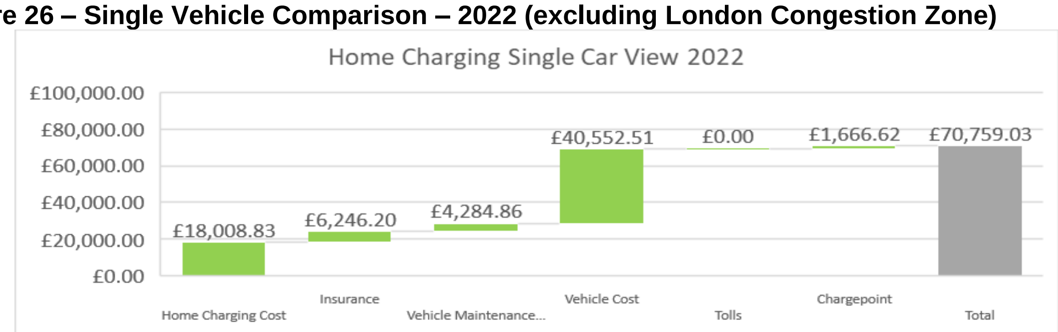
3.3.1.5.1 Single Vehicle Comparison – 2022 (excluding London Congestion Zone)

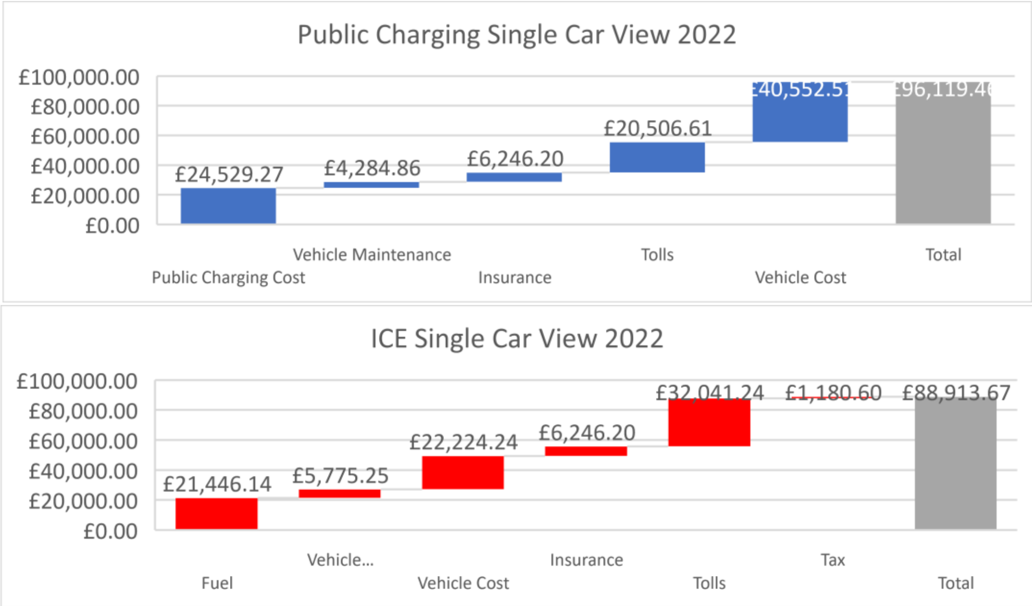
In the 2022 scenario, both the diesel van and the electric van are affected by increased costs to power the vehicle. However, the rises in price per kWh for electricity was more significant than the increased in cost for diesel fuel, as has been noted in the sensitivity analysis in section 3.3.1.7.

Using 2022 electricity prices, seen in Table 21, for home charging, without London Congestion Charge, there is a net loss of ~£14k over eight years and a loss of ~£12k over five years compared against ICE. Comparing public charging against an ICEV, using 2022 electricity prices, there is a net loss of ~£19k over eight years and ~£15k over five years (Figure 26).

Considering the 2022 scenario, and excluding the Congestion Charge, the ICE van works out ~£14k cheaper over an eight year lease period and ~£12k cheaper over a five year lease period when compared with a home charging EV, and ~£19k (eight year) and ~£16k (five year) cheaper than a public charging EV. As with the 2021 case, absence of the congestion charge prevents either the public or home charging EV from reaching parity with ICEV. However, the OZEV subsidy expiry and the sharp rise in the price of electricity are also fundamental factors to this disparity between EV and ICEV.

Figure 26 – Single Vehicle Comparison – 2022 (excluding London Congestion Zone)

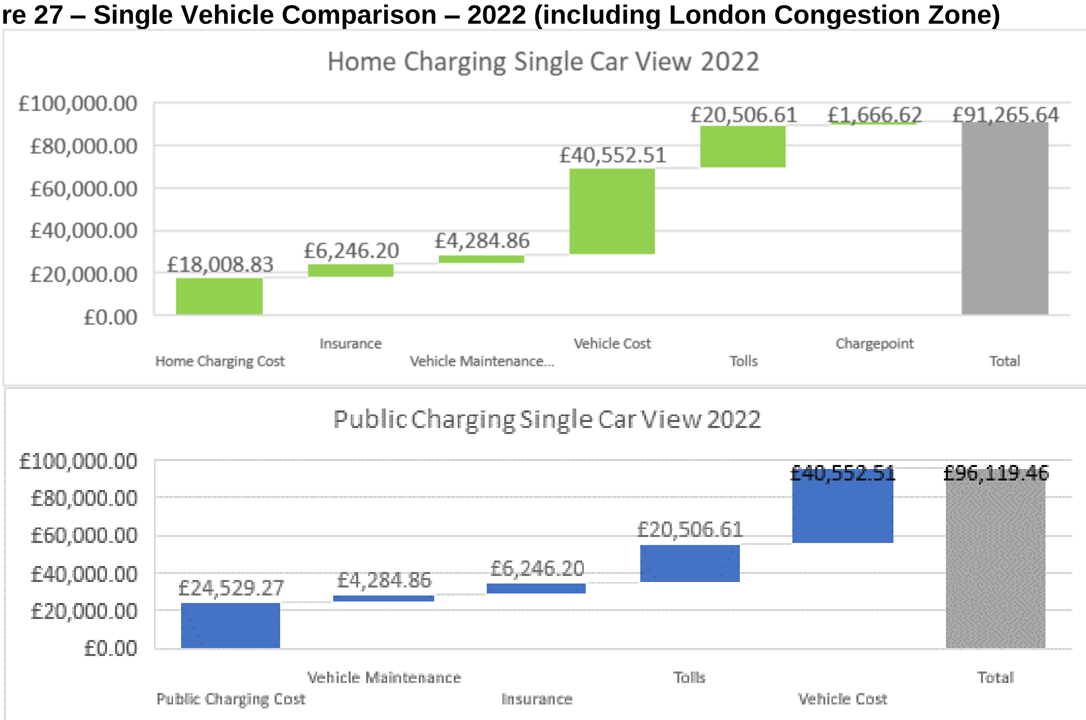


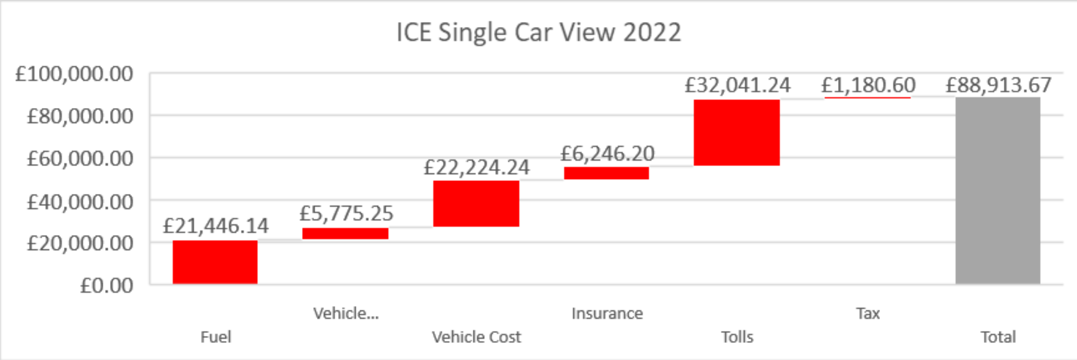


3.3.1.5.2 Single Vehicle Comparison – 2022 (including London Congestion Zone)

When the London Congestion Zone is included, these losses are less pronounced, and ICE remains the most economical option in the 2022 case. There is a net loss of ~£2.3k for a home charging van compared to ICE over eight years and a ~£2.2k net loss over five years (Figure 27). For a single-vehicle public charging compared to an ICEV over eight years there is a net loss of ~£7k and over five years there is a net loss of~£3k. Even with the benefit of the daily £15 charge for ICE vans until 2025, the EVs cannot reach parity under the 2022 scenario.

Figure 27 – Single Vehicle Comparison – 2022 (including London Congestion Zone)





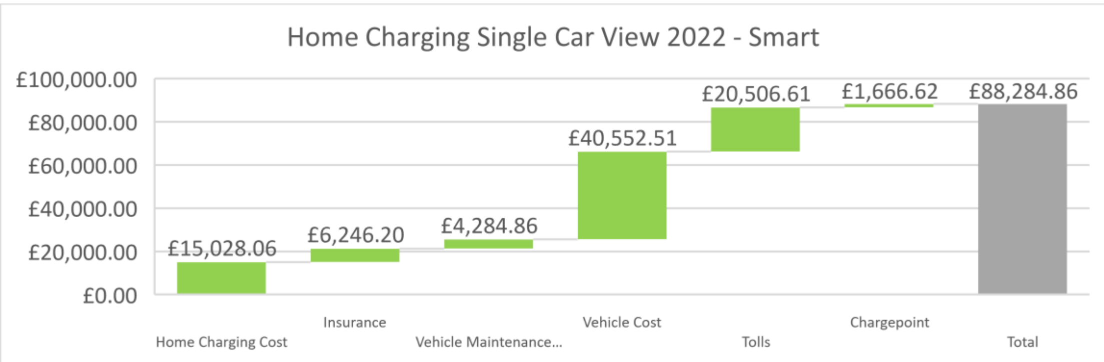
Single Vehicle Conclusions

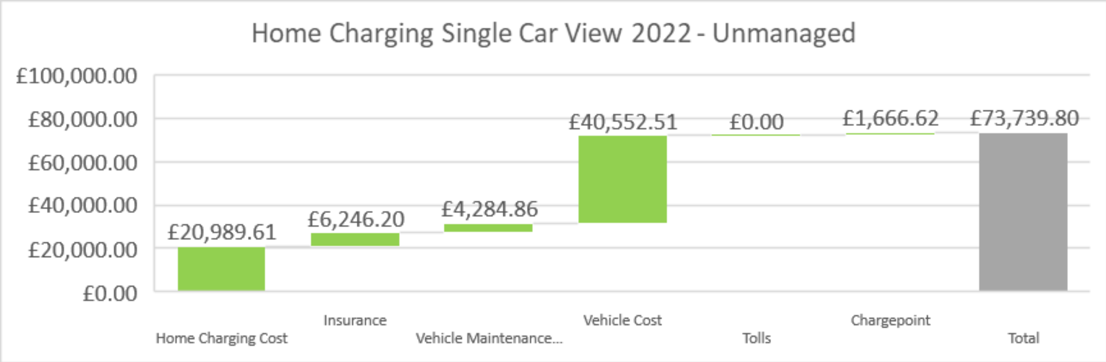
- A home charging EV was consistently the cheaper option compared with public charging. This was mostly because of the cheaper cost of electricity at home rather than commercial prices at public charging stations.
- EVs only reached net savings against ICEV when the London Congestion Zone was included, showing the impact such policies make on EV adoption. However, this was only possible in the 2021 scenario as rising costs made ICEV cheaper than EV in 2022
- The cost difference between EV and ICEV is exaggerated in the 2022 scenarios compared with 2021. The increased electricity prices and removal of the OZEV subsidy on home charging points have impacted the EV TCO.

3.3.1.6 2022 Single Vehicle View Unmanaged charging vs Smart Charging

The economic benefit that smart charging can yield for a home charging fleet was analysed. The cost of running an unmanaged charging schedule on a home charging van was compared against a van smart charging on an optimised schedule. For an unmanaged charging schedule, the van was modelled to charge 80% of the time on the more expensive daytime (£0.37 / kWh) tariff and the remaining 20% on the cheaper night-time tariff (£0.21 / kWh). A smart charging schedule was assumed to be the opposite of the unmanaged charging schedule, as Table 22 outlines.

Figure 28 – Smart vs Unmanaged Charging Comparison – 2022





The conclusion is that a single EV charging at home can save up to ~£6k over the course of an eight year lease compared to an unmanaged schedule. This demonstrates that there is a significant cost difference between unmanaged and smart charging which amounts to an 8% cost decrease for a single EV over eight years. For an entire EV fleet, smart home charging would amount to a £57 million saving. This indicates how much of a priority smart charging is in supporting cost-effective EV fleet transitioning.

There is a disparity between how many drivers Centrica wants to have on smart charging tariffs and how many it has currently. Currently, only 10% of Centrica's fleet are on time of use electricity tariffs, which are required in order to release the benefits in optimising the charge. Considering Centrica's current charging case across the fleet– outlined in Table 22 – if Centrica were to increase the percentage of those who smart charge from around 10% to 50%, there would be a ~£14m net saving over an eight year window from £668 million to £654 million. If Centrica were to increase the proportion of the home charging vehicles that are smart charging to 90% there would be a saving of ~£29m over eight years.

Although smart charging can add immediate and significant economic benefit, relative to the comparative cost of leasing the vehicles, this saving is small. Figure 29 and Figure 30 demonstrate that the gap in lease prices between the ICEV and EV dictates that smart charging cannot alone lift EVs to TCO parity; even with up to 90% of the home-charging fleet smart charging, there is still a cost deficit for ICEV.

Figure 29 – Impact of 50% Smart Charging on TCO – 2022

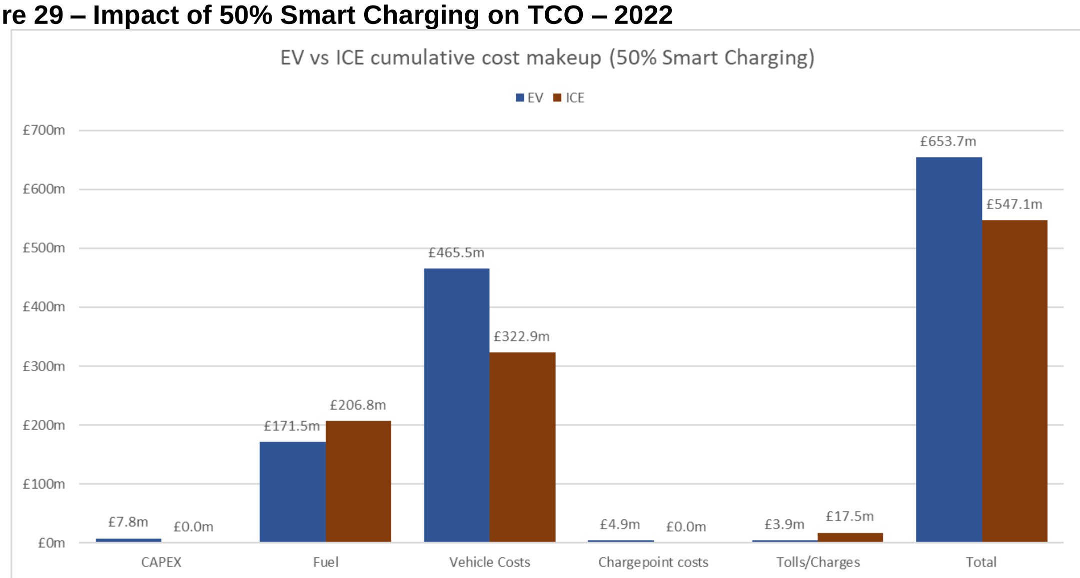
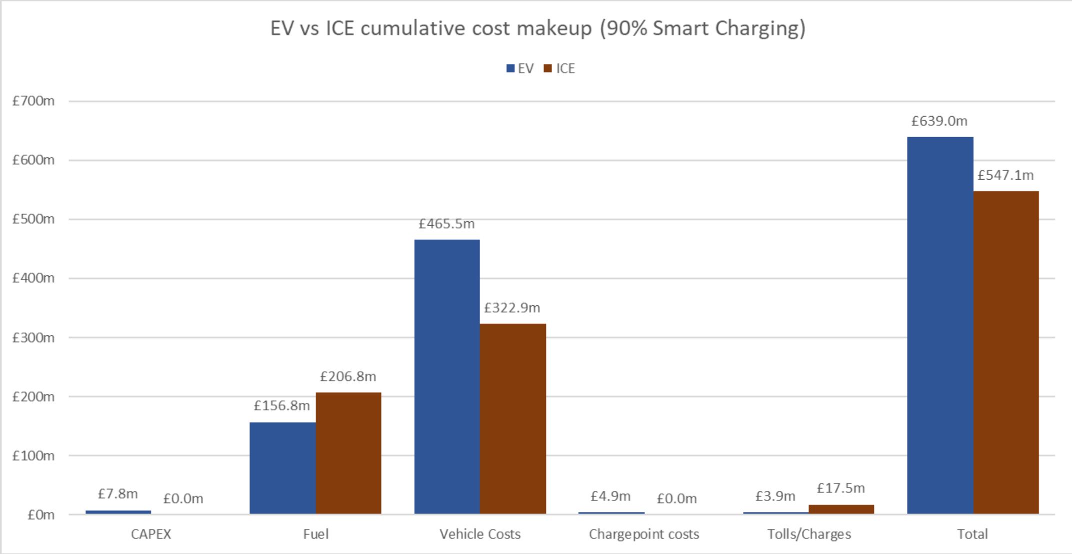


Figure 30 – Impact of 90% smart charging on TCO - 2022



Smart charging conclusions

- Smart charging can have a positive effect on EV TCO, reaching savings of up to 8% of the total cost. Expanding the percentage of the fleet that smart charge can result in large TCO savings when aggregated across the fleet (up to £29m if 90% of the home charging vehicles deployed smart optimisation on their charging).
- Smart charging alone is not sufficient to bridge the TCO gap between EV and ICEV because of the difference in lease costs.

3.3.1.7 Sensitivity Analysis

Sensitivity Analysis was conducted on the following variables in order to gauge which had the most potent influence on the overall TCO of Centrica's fleet. Every possible charging composition of the fleet was included, and then the cost difference adjustments on the factors made were compared to give insight into the model sensitivity.

3.3.1.7.1 Analysis Overview

The following variables were prioritised for the analysis for various reasons. Either it was important to view the cost difference they made, or it was important to include them to allow comparison with other factors. They are summarised in Table 24.

Table 24 – Selected Factors for Sensitivity Analysis

Factor	Explanation
Baseline	Standard assumptions used, consistent with input from Optimise Prime partners.
High electricity costs	Cost of electricity increased by 20%.
Low electricity costs	Cost of electricity reduced by 20%.
High fuel costs	Cost of diesel increased by 20%.
Low fuel costs	Cost of fuel reduced by 20%.
Low mileage	Mileage reduced to 50 miles per day (at the lower end of British Gas drivers' self-reported daily distances).

Factor	Explanation
High mileage	Mileage increased to 120 miles per day (at the top end of British Gas drivers' self-reported daily distances).
Inc. London Congestion Zone	Daily London Congestion Zone charge included, including EV payments from 2025.
High EV price	Monthly EV lease price increased by 20%.
Low EV price	Monthly EV lease price reduced by 20%.

A range of scenarios were tested. An ICE scenario was used as a benchmark, and then three scenarios, per charging type, were designed to cover most of the types of charging strategy that the British Gas engineers would be operating for their EVs. The selected scenarios are summarised in Table 25.

Table 25 – Selected Scenarios for Sensitivity Analysis

ICE_ TCO (£)	EV Public Charging – Blended_ TCO (£)	EV Public Charging – Rapid_ TCO (£)	EV Public Charging- Slow_ TCO (£)	EV Home Charging – Blended_ TCO (£)	EV Home Charging- Smart_ TCO (£)	EV Home Charging– Unmanaged _ TCO (£)
Regular ICEV	Public charging EV using a blend (50:50) of electricity from Rapid and Slow CPs	Public charging EV using mostly Rapid charging (80:20 Rapid to Slow split)	Public charging EV using mostly Slow charging (80:20 Slow to Rapid split)	Home charging EV optimising their charging half of the time (50:50 smart and unmanaged charging)	Home charging EV following a smart charging schedule	Home charging EV following an unmanaged charging schedule

The results were consistent across both the 2021 and 2022 scenarios. For both, the London Congestion Charge was shown to have a significant impact in influencing the TCO of an EV vs ICEV. When the Congestion Charge is included, all of the EV scenarios were cheaper than the ICEV apart from the Rapid charging EV. Although the Congestion Charge is due to expire in 2025, this analysis proved the Congestion Charge to be a strong economic measure that can incentivise EV adoption, which is an important consideration if other cities choose to implement tolls that favour EV over ICEV in future.

Similarly, a reduction in the lease price of EVs can improve its TCO. In the 2021 scenario, a 20% reduction in price resulted in a home charging EV on a smart, optimised charging schedule, to achieve net savings compared with an ICEV. A public charging EV using slow CPs was within £500 of reaching parity. With EV OEMs building economies of scale, and with prices of batteries expected to fall over the next couple of years, this should also improve the EV TCO.

For the 2021 scenario, the influence of reductions in price of electricity had a minor impact.

Figure 31 – Sensitivity Analysis on a Single Vehicle Case – 2021

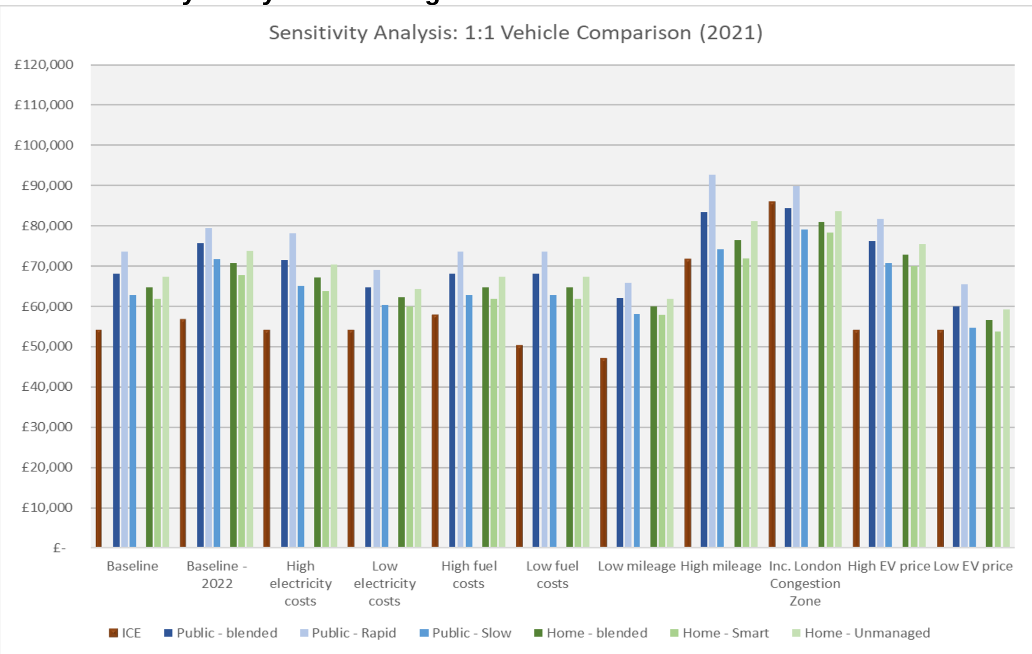


Figure 32 – Cost Impact from Analysis – 2021

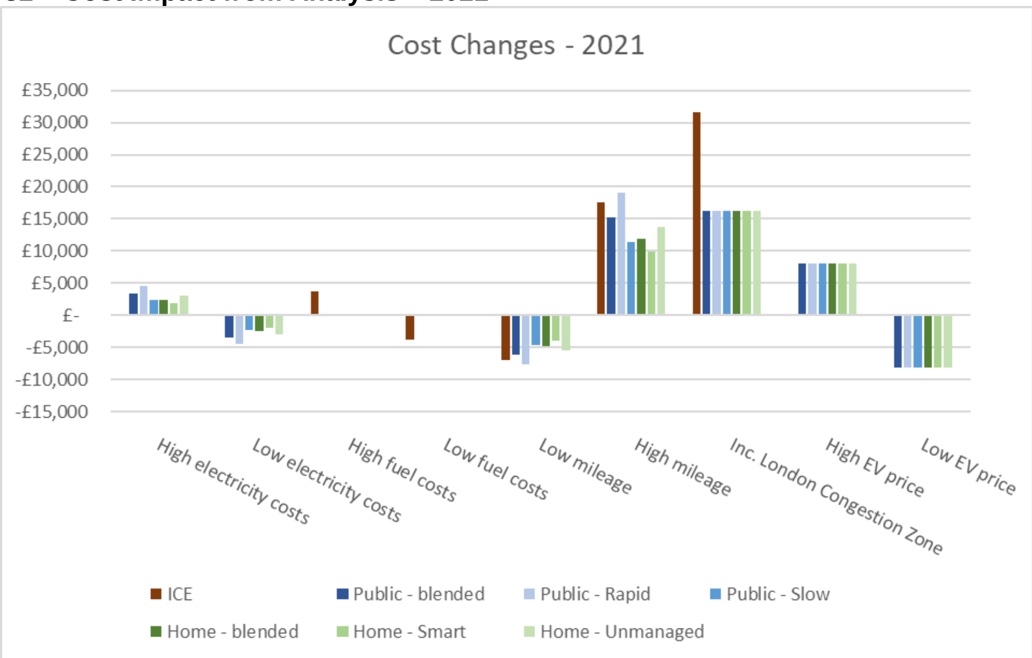


Table 26 – Data supporting 2021 Sensitivity Analysis

	ICE_ TCO (£)	EV Public Charging – Blended_ TCO (£)	EV Public Charging – Rapid_ TCO (£)	EV Public Charging-Slow_ TCO (£)	EV Home Charging – Blended_ TCO (£)	EV Home Charging - Smart_ TCO (£)	EV Home Charging– Unmanage d _ TCO (£)
Baseline	54,205	68,161	73,564	62,758	64,696	61,964	67,428
Baseline – 2022	56,872	75,613	79,525	71,701	70,759	67,778	73,740
High electricity costs	54,205	71,576	78,060	65,093	67,155	63,876	70,434
Low electricity costs	54,205	64,745	69,068	60,423	62,237	60,051	64,423
High fuel costs	57,961	68,161	73,564	62,758	64,696	61,964	67,428
Low fuel costs	50,450	68,161	73,564	62,758	64,696	61,964	67,428
Low mileage	47,190	62,057	65,916	58,198	59,959	58,007	61,910
High mileage	71,744	83,420	92,681	74,158	76,539	71,855	81,223
Inc. London Congestion Zone	85,829	84,443	89,846	79,041	80,978	78,246	83,711
High EV price	54,205	76,271	81,674	70,869	72,806	70,074	75,539
Low EV price	54,205	60,050	65,453	54,648	56,585	53,853	59,318

In the 2022 scenario, due to the peaking electricity prices and the removal of the OZEV subsidy, only the smart charging EV with the Congestion Charge scenario reached a net saving against the ICE benchmark. Reductions in electricity prices made more of an impact on the TCO, even with reductions in EV lease price, parity still could not be reached.

The ICE baseline increased by ~£2,758 due to the rises in fuel prices. This is far lower when compared to the price impact that EV TCOs have suffered. The average increase in cost for EVs taken from the six scenarios was £6,758, with the highest increase – experienced for public, slow charging vans – was £8,942. In effect, EV TCOs have on average experienced price rises double that of ICEVs, and in some cases the prices have increased by three times more than ICEV.

Figure 33 – Sensitivity Analysis on a Single Vehicle Case – 2022

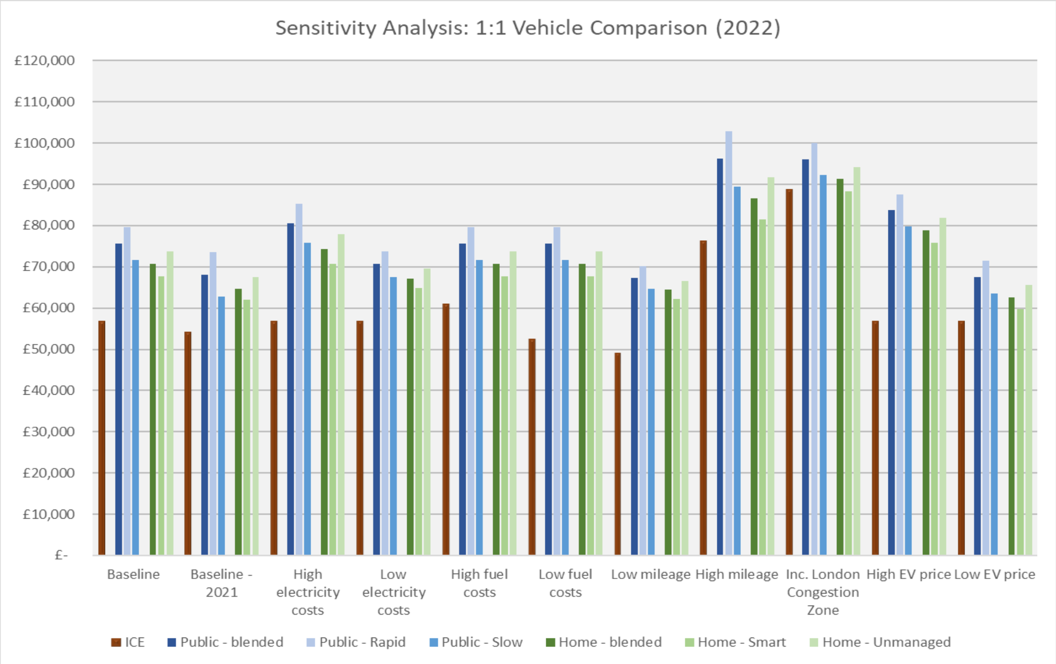


Figure 34 – Cost Impact from Analysis – 2022

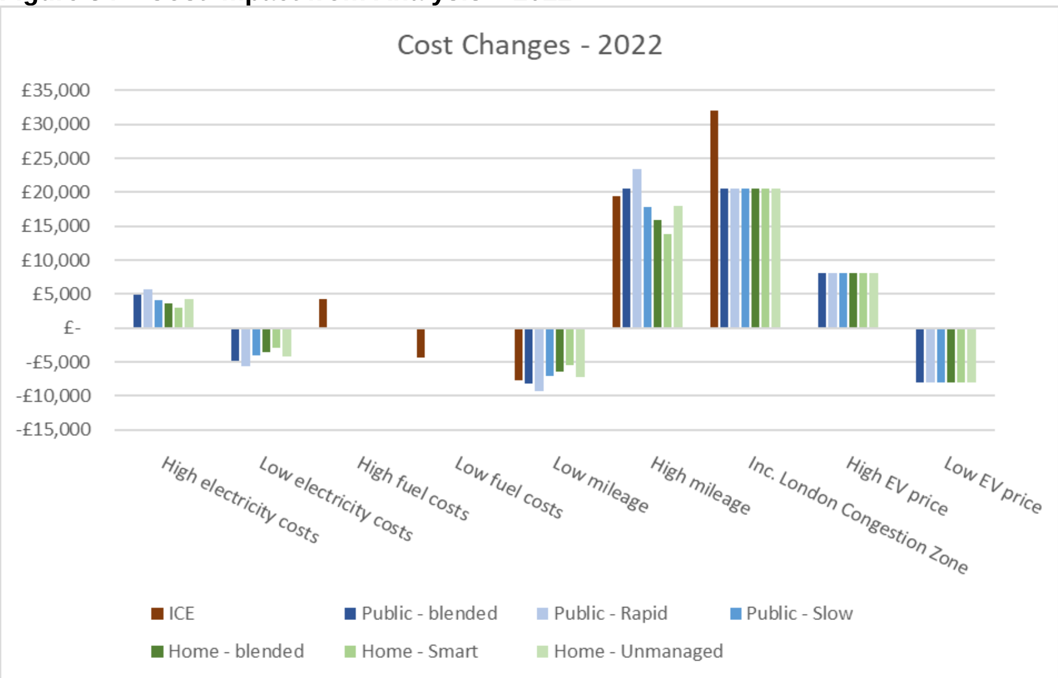


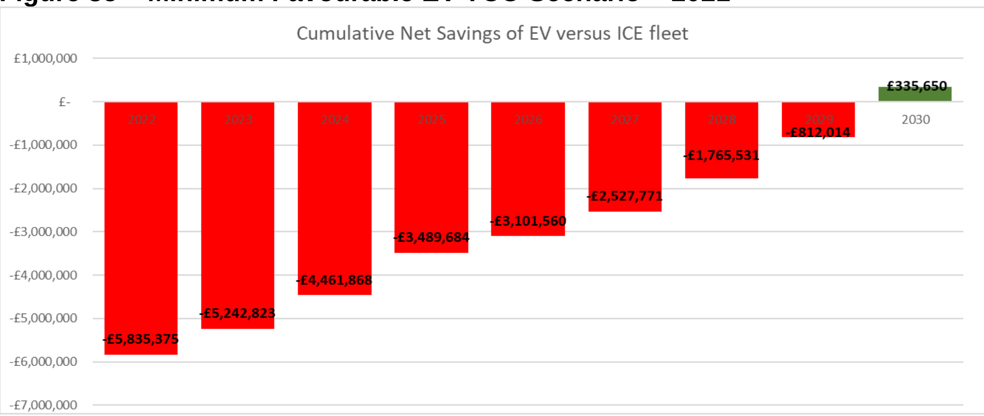
Table 27 – Data Supporting 2022 Sensitivity Analysis

	ICE TCO (£)	EV Public Charging – Blended TCO (£)	EV Public Charging – Rapid TCO (£)	EV Public Charging - Slow TCO (£)	EV Home Charging – Blended TCO (£)	EV Home Charging- Smart TCO (£)	EV Home Charging– Unmanaged TCO (£)
Baseline	56,872	75,613	79,525	71,701	70,759	67,778	73,740
Baseline – 2021	54,205	68,161	73,564	62,758	64,696	61,964	67,428
High electricity costs	56,872	80,519	85,213	75,824	74,361	70,784	77,938
Low electricity costs	56,872	70,707	73,837	67,577	67,157	64,773	69,542
High fuel costs	61,162	75,613	79,525	71,701	70,759	67,778	73,740
Low fuel costs	52,583	75,613	79,525	71,701	70,759	67,778	73,740
Low mileage	49,095	67,380	70,175	64,586	64,389	62,260	66,519
High mileage	76,316	96,194	102,901	89,488	86,683	81,573	91,793
Inc. London Congestion Zone	88,914	96,119	100,032	92,207	91,266	88,285	94,246
High EV price	56,872	83,723	87,636	79,811	78,870	75,889	81,850
Low EV price	56,872	67,502	71,415	63,590	62,649	59,668	65,629

3.3.1.7.2 2021 Lease cost sensitivity analysis – What's needed for EV TCO cost parity?

Analysis of what is needed both in 2021 and 2022 for an EV to make savings against ICEV, following the realistic, baseline case outlined in Table 27, concluded that by adjusting the lease price for EV, parity – deemed within £500k for the whole fleet – can be achieved with a 19% reduction – see Figure 35. This would require lease prices to drop to £325 per month from £400 per month for the fleet.

Figure 35 – Minimum Favourable EV TCO Scenario – 2021



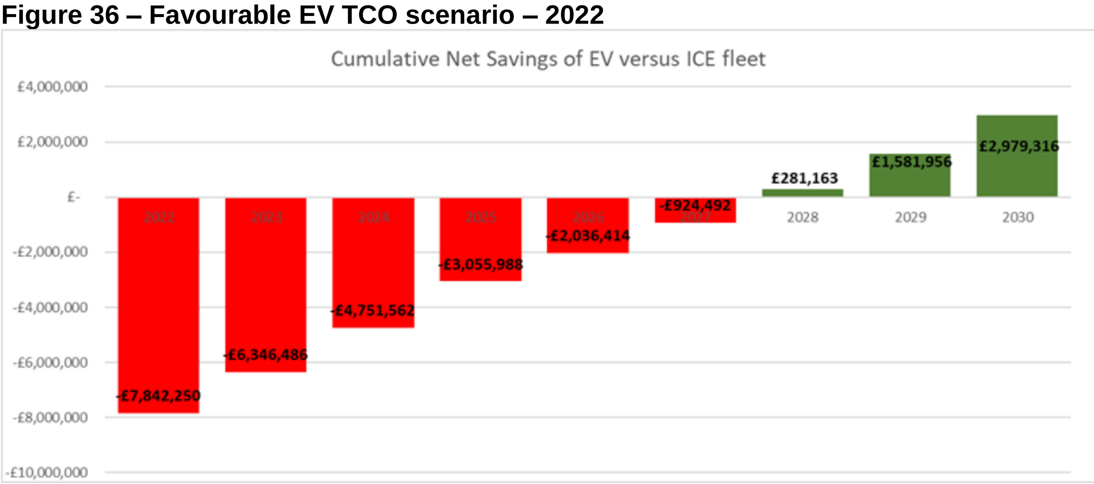
3.3.1.7.3 2022 Lease cost sensitivity analysis – What's needed today for significant savings?

For 2022, a 34% reduction in lease price cost is required. This would require the cost of leasing a EV van to reach £264 vehicle cost per month but would result in savings of ~£3m across the fleet over an eight year period. For the fleet over eight years this would mean that there would need to be a £10 million saving for EV on lease costs alone for EV to yield significant savings with 2022 electricity prices.

Sensitivity Analysis conclusions

- The most impactful factor on EVs reaching TCO parity with ICEVs is the lease price, which is the largest part of the total cost. Congestion charges were also shown to be influential EV incentives.
- Significant lease cost reductions would be required to yield net savings for EV (a reduction in monthly lease costs by 34%) if the relative costs of electricity and fuel do not change.
- EV TCOs have on average experienced price rises double that of ICEVs, and in some cases the prices have increased by three times more than ICEV, due to recent volatility in energy prices.

Figure 36 – Favourable EV TCO scenario – 2022



3.3.2 Summary of Key Learnings

Reducing the lease price between 20%-30% using 2021 prices is necessary for EV to be at a competitive level compared to ICEV TCO. Due primarily to increased electricity costs in 2022, lease costs would now need to fall by 30-50% to reach TCO parity.

The sensitivity analysis has shown a 19% decrease in EV price is sufficient for approximate parity under 2021 conditions. The 2022 case demonstrated that a 34% decrease in EV lease price could yield close to £3m in savings across the fleet, but this would require large shifts in pricing from OEMs and/or leasing providers. It is likely that reductions in lease prices would need to be accompanied by other cost saving measures – such as capitalising on smart charging for the home charging vehicles – in order to reach a realistic case where EV could be on par with ICEV.

The electricity price increases in 2022 have made the commercial case for transitioning to an EV fleet more uncertain

Considering the prices in 2022 for a single ICE van against an EV, rises in fuel prices have caused a £2,667 increase in fuel costs, whereas the rises in cost of power for the EVs is far more severe at £5,713 extra, for a home charging van, and £7,452 for a public charging van. With the price increases, EVs have suffered on average double that of ICEV, it is likely that reductions in EV price will need to be accompanied by other measures to ensure EVs can regain competitiveness in TCO against ICEV.

Government subsidies and charges can make a significant difference to EV business cases

Based on the assumption that electricity prices will reduce once inflation in the UK subsides, if more cities start to introduce congestion charge zones, as seen in London, there may be additional savings in the future for EV fleets. An example of this is in Oxford, which will have an expanded zero emission zone and a £2 to £10 per day fee for all vehicles that are not 100% emission free, this could help swing the balance back towards electric in this region. The sensitivity analysis concluded that EV benefit from congestion charging to be the most influential factor, and so maximising the scope of this policy could be useful in encouraging adoption.

Smart charging can improve EV TCO competitiveness, although this is not always possible for home-based fleets

A smart charging EV was consistently the most cost-effective option in the TCO assessment. If Centrica could ensure that even half of its home charging fleet were smart charging, then they could achieve savings of around £14m. Optimising charge schedules for predominantly home-based charging fleets around time-of-use tariffs should be priority.

However, as will be explored in Section 6. there are currently barriers to the use of smart charging, with Centrica unable to ensure drivers use a specific tariff and little incentives for drivers to change.

3.4 Total Cost of Ownership from a Mixed Fleet – an example of a driver on the Uber platform

3.4.1 Introduction

The Uber TCO aims to model the total costs of owning and operating an Uber-licensed vehicle PHV on the Uber platform, comparing a petrol baseline vehicle to an electric model. Unlike with Royal Mail and Centrica, this model is based on a single vehicle view rather than a fleet view, due to the business model run by Uber where the vehicle and operational costs are covered by the drivers. The TCO helps to understand the decision-making of Uber drivers when selecting a vehicle. The behavioural surveys highlighted that EV price is one of the main barriers to switching to EVs (see Section for more detail).

3.4.1.1 Persona approach

Five main Uber driver personas were created, based on data obtained from the questionnaire results. The personas are then split into different scenarios, which represent the options available to each persona in terms of vehicle purchase or leasing options.

1. **New ICE**: is a full-time Uber driver who buys or leases a Toyota Prius as it is the vehicle the driver has been driving and enjoys the convenience of refuelling. The driver understands there will be a switch to EVs at some point in the future, but is not prepared to be one of the first to do it. The driver thinks finding a place to charge an EV and longer stops will mean a longer working day with fewer paid trips.

The New ICE persona represents a reliable TCO comparison baseline because of the availability of data on new vehicle pricing, leasing and financing deals in the market. However, this persona represents a minority of Uber drivers, who typically tend to buy second-hand vehicles.

2. **New EV – Home CP**: buys or leases an EV and has a CP installed at home. It is convenient for the driver to charge at home, meaning a full "tank" every morning. The driver selects a Kia eNiro as a reliable, long-range EV – avoiding the current congestion charges and reducing fuel costs. Despite mostly charging at home, on occasion the driver will need to charge at a rapid CP in the city (from questionnaire results and data science results, this is roughly 25% of the total electricity used each year).

3. **New EV – Public CP**: buys or leases an EV despite not having off-street parking at home. The driver believes the public charging infrastructure in London will be convenient enough to cover energy needs during the day and does not mind making a few extra trips and occasionally waiting while the vehicle charges up. While the fuel cost differential compared to an ICEV will not be as high as charging at home, there will be advantages in avoiding the congestion charge and receiving incentives from Uber for the completed EV trips.

These two new EV personas represent a group of early adopters, who thus far account for the minority of Uber drivers.

4. **Second-hand ICE**: buys a second-hand ICEV to keep a low initial investment, and to avoid a longer-term commitment on a financing or leasing deal. The driver does not have off-street parking and is reluctant to consider a new EV for this reason. Because of the high up-front purchase cost or high fixed cost of a financing or a leasing deal, the driver would definitely consider buying a used EV, but the second-hand EV market is limited. If the driver switched to an EV, the driver would need to rely on public charging, but is concerned about the availability and reliability of public CPs.

5. **Second-hand EV – Public CP**: is a part-time Uber driver who wants to switch to an EV because he/she is conscious about urban air pollution and believes more customers will be choosing green transport options. As driving hours and income are unpredictable, the driver wants to avoid the commitment of a long-term financing deal or a high fixed cost of a leasing deal. The driver considers the growing second-hand EV market for a reliable, recent model, with the knowledge that older EV models may not have the required battery size, range and reliability. Charging would be at public charging stations.

Second-hand ICEV drivers represent the largest group of current Uber drivers. This final persona represents an ideal and realistic scenario from a TCO point of view, with lower initial investment and lower running cost compared to ICEV. However, only a small portion of drivers fall into this category, due to limited supply of suitable used EVs and unavailability of off-street parking.

3.4.1.2 Main inputs, outputs and assumptions

The main model inputs and outputs are detailed in Figure 37, Table 28 & Table 29. These were discussed and validated with Uber, who provided guidance based on internal research and data. By changing key inputs, such as fuel and electricity costs, home vs public charging, vehicle power efficiency, and mileage driven, it is possible to run different scenarios based on the personas described above. Some key assumptions remain unvaried for each scenario, such as the London Congestion Charge of £15 per day and inflation rates. This is further discussed in the sensitivity analysis section.

- **Vehicle choices:** based on input from the Uber Clean Air team, the vehicle choices include two ICEVs and three EVs. These reflect the most used ICEV, which is the Toyota Prius, and the EVs showing the strongest uptake by Uber drivers: the Kia eNiro 2, and the MG MG5. The second-hand vehicle choices are a Toyota Prius 2015 and a Nissan Leaf 2018. See Table 29 for more detail on costs and power efficiencies for these vehicles.
- **Power efficiency:** The fuel and power efficiencies were obtained from real-life mileage databases for city-driving, in order to obtain a more realistic range to accurately calculate operational costs. While WLTP ranges are industry-standard, they often do not reflect the achieved mileage ranges due to traffic conditions, temperature, driver behaviour, and other factors.
- **Tolls/charges:** based on input from the Uber Clean Air team, as well as trip data analysed by the Optimise Prime data science team, Uber drivers often drive within London's Congestion Zone. As a baseline, it has been assumed that a driver will enter the Congestion Zone on 75% of the days driven per year. Currently, the Congestion Zone charge exemption for EVs is due to end at the end of 2025, meaning that EV drivers in this model will start paying the charge from January 2026.
- **Distance driven:** assumed 50,000km per year driven by Uber drivers, which was validated by the Uber Clean Air team. Sensitivity analysis will also show how an increase or decrease of driving mileages would affect the TCO.
- **Percentage of times charged at public CP:** a small percentage of drivers will be able to install a CP at home. Additionally, drivers who charge at home may need top-up charges during their shift. For this reason, EV Home CP persona uses public CPs 25% of the time, while EV Public CP always uses public CPs. This in turn affects their total electricity costs.
- **TCO period:** a period of 5 years was selected based on the high vehicle utilisation by Uber drivers.

Figure 37 – Inputs and outputs of the Uber TCO model

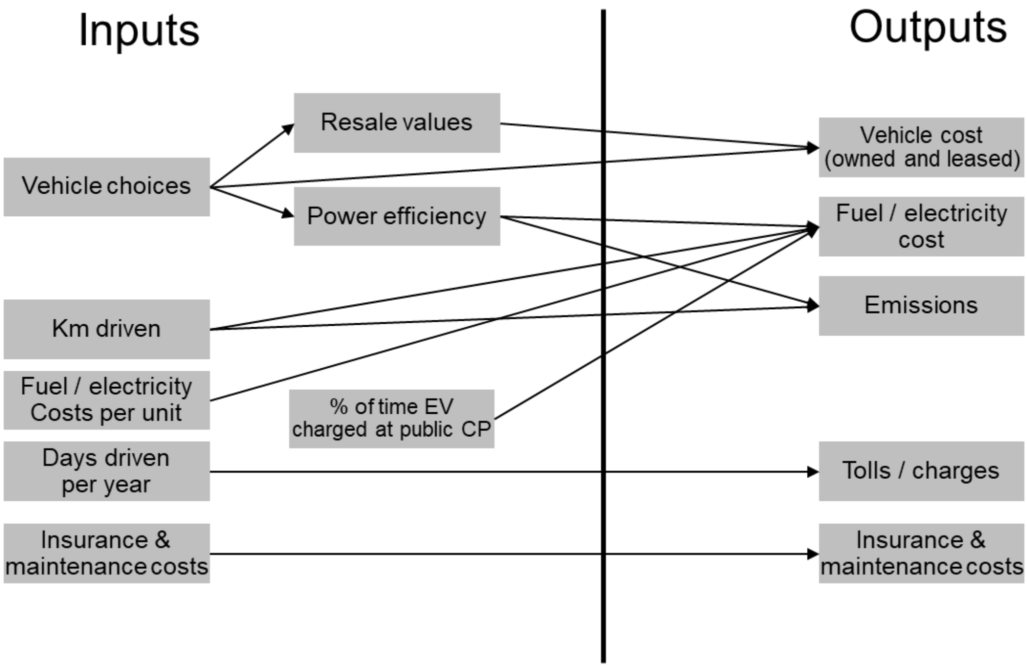


Table 28 – Baseline operational assumptions for Uber TCO. All assumptions updated as of 22 February 2022

Key assumptions	Inputs	Sources
Home CP cost	£859.00	Uber partner website (EO charging) – OZEV grant excluded.
Km driven per year	50,000	Uber input
Days driven per year	250	Uber input
Fuel efficiency (L/100km) – ICEV	3.7	Hitachi research based on WLTP ranges and expected real range (average of user inputs based on city driving). 3.7 for new ICE, 5.6 for older ICE.
Power efficiency (Wh/km) – EV	236	Hitachi research based on WLTP ranges and expected real range. EV database. Varies based with model of EV (see table 2)
ICEV maintenance cost per month	£61.42	Online PHV-driver forums, Hitachi research Increased by 30% for second-hand vehicles
EV maintenance cost per month	£42.99	Online PHV-driver forums, Hitachi research Increased by 30% for second-hand vehicles
Petrol fuel cost (£/L)	£1.47	Average UK price (https://www.racfoundation.org/data/uk-daily-fuel-table-with-breakdown)
Electricity home charge cost (£/kWh)	£0.25	Hitachi estimate based on 2022 electricity price trends
Electricity public charge cost (£/kWh)	£0.35	BP pulse membership prices
% of energy utilised at public CP	EV home CP = 25% EV public CP = 100%	Hitachi estimate based on data science and questionnaire results

Key assumptions	Inputs	Sources
Vehicle resale value after five years (% of vehicle purchase price)	20% for new, 33% for second hand	Hitachi research on used vehicle prices, averaged across multiple sources and vehicle types
Yearly insurance cost	£2,500.00	Uber input, Hitachi research Reduced by 40% for second-hand vehicles
Vehicle financing terms	Five year contract at 7.9% APR, £5,000 down-payment	Hitachi research. Assumed same rates for ICEV and EV for comparability.

Table 29 – Vehicle cost assumptions for the Uber TCO model

Vehicle choice	Cost (owned)	Lease cost (monthly)	Power efficiency (Wh/km)	Fuel efficiency (L/100km)
Nissan Leaf EV N-Connecta 40kWh	£29,995.00	£992.00	138	NA
MG5 EV Long Range Exclusive 60kWh	£27,250.00	£1,079.00	140	NA
Kia e-Niro 2 EV 64kWh	£34,995.00	£1,122.00	136	NA
Second-hand Nissan Leaf EV Acenta (2018) 40kWh	£19,290.00	NA	140	NA
Toyota Prius	£25,000.00	£949.00	NA	3.7
Second-hand Toyota Prius	£13,500.00	NA	NA	5.6

3.4.1.3 Opportunity cost of rapid vs ultra-rapid charging

Currently, charging EVs takes longer than refuelling an ICEV. For Uber drivers, a significant stop represents an opportunity cost when not accepting paid trips. When in need of charging, Uber drivers in London have two main options: a rapid CP with a maximum output of 50kW, or an ultra-rapid CP which can output up to 150kW. Table 30 shows the opportunity cost of charging, given a £25/hour revenue estimate for Uber drivers in London. While the ultra-rapid CP costs more per unit, the total cost of charging when considering foregone revenue is higher for a rapid CP. This effect is more pronounced in slower CPs, which would keep a driver stopped for significantly longer time.

When analysing results for the EV Public CP persona, opportunity cost will be discussed as an additional cost component to the EV TCO.

Table 30 – Opportunity cost of rapid and ultra-rapid charging

	Rapid CP (50kW)	Ultra-rapid CP (150kW)
Cost per kWh (bp pulse membership)	35p	50p
Time taken to charge a 64kWh EV from 20% to 80%	45 mins	15 mins[16]
Charging cost	£12.30	£14.60
Opportunity cost	£18.75	£4.70

[16] EV must be capable of accepting 150kW charge rate to charge in this time

	Rapid CP (50kW)	Ultra-rapid CP (150kW)
Total cost (including opportunity cost)	£31.05	£19.30

The opportunity cost of charging is reduced when EV drivers are able to combine charging with a regular break – this is discussed further in the behavioural section of this report, section 4.2.3.3.2. Additionally, it is beneficial for EV drivers to charge the vehicle fully overnight at a cheaper public on-street slow/fast charger, and only utilise rapid chargers to top-up during the day when required.

3.4.2 Overview of results

Table 31 summarises the headline results from the Uber TCO model, split by the different personas and scenarios. The five year TCO can be used to compare between ICEV and EV costs, with further scenarios such as leasing, financing, and second-hand vehicles. The split of fixed and variable costs shows what drivers can expect in terms of regular monthly payments, such as leasing, insurance, or tax, compared to running costs such as petrol and electricity.

3.4.2.1 Summary of key findings

Five main persona comparisons are analysed in the results section, with the following key learnings:

- **New ICE vs New EV – Home CP (outright purchase):** Given the initial higher CAPEX of the EV and the CP installation, the EV remains the more expensive option in the first two to three years of its lifetime. Savings in congestion charges and running costs mean a lower TCO for EV compared to ICEV over the five year TCO period.
- **New EV – Home CP vs New EV – Public CP (outright purchase):** public charging increases operational costs of driving an EV, yet the TCO remains beneficial towards EV owners compared to ICEV over the long-term. However, the opportunity cost of public charging can be up to £15,625 over the five year period when top-up charging every shift, thus reducing the benefit.
- **New EV – Public CP (outright purchase vs. leasing and financing):** Leasing and financing may be the most likely choice for PHV drivers when switching from a second hand ICEV to a new EV. Despite the initial CAPEX being lower, the high leasing costs mean a higher five year TCO compared to vehicle ownership.
- **Second-hand ICE vs Second-hand EV – Public CP (outright purchase):** pre-owned vehicles had the lowest TCOs: the lower vehicle costs meant the operational savings from the EV made up for the initial CAPEX gap of £5,800 between the second-hand Toyota Prius and the pre-owned Nissan Leaf. The opportunity cost of public charging can reduced if top-ups are required during un-planned breaks.

Table 31 – Overview of Uber TCO results for different scenarios

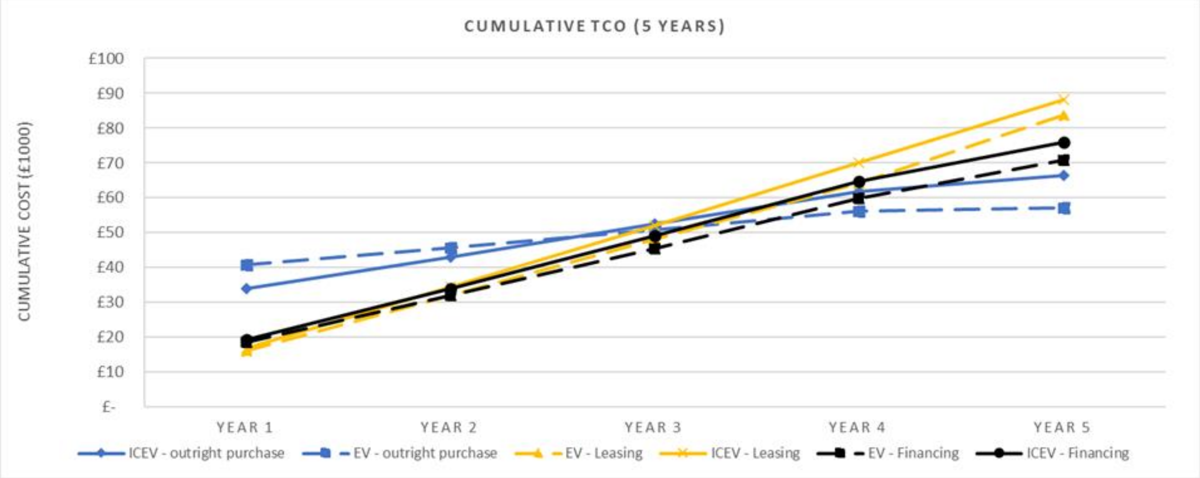
Persona	Scenario	Scenario description	5-year TCO (£1,000s)	Initial CAPEX investment (£1,000s)	Split of fixed / variable operational costs (percentage, excludes CAPEX)
New ICE	New ICE – Outright purchase	Toyota Prius bought with no financing	66.4	25	27 / 73%
	New ICE – Leasing	Toyota Prius, leased	88.3	0.5	67 / 33%
	New ICE – Financing	Toyota Prius, financed	76.0	5	62 / 38%
New EV – Home CP	New EV – Home CP – Outright purchase	Kia eNiro 2 bought with no financing. Home charging (75% of total energy usage)	57.2	35	28 / 72%
	New EV – Home CP – Leasing	Kia eNiro 2, leased	83.8	0.5	83 / 17%
	New EV – Home CP – Financing	Kia eNiro 2, financed	70.7	5	84 / 16%
New EV – Public CP	New EV – Public CP – Outright purchase	Kia eNiro 2 bought with no financing. Public charging	59.9	35	27 / 73%
	New EV – Public CP – Leasing	Kia eNiro 2, leased. Public charging	86.5	0.5	80 / 20%
	New EV – Public CP – Financing	Kia eNiro 2, financed. Public charging	73.4	5	81 / 19%
Second-hand ICE	Second-hand ICE – Outright purchase	Pre-owned Toyota Prius, bought with no financing	60.5	13.5	23 / 77%
Second-hand EV – Public CP	Second-hand EV – Public CP – Outright purchase	Pre-owned Nissan Leaf	42.8	19.3	36 / 64%

3.4.3 Scenario comparisons

3.4.3.1 Persona comparison: New ICE vs New EV – Home CP

This analysis explores the comparison of a five year TCO for a new ICEV and a new EV with a home CP, under different financing scenarios (outright purchase, leasing and financing). While the outright purchase is an unlikely option for drivers, it provides an initial like-for-like comparison between EV and ICEV.

Figure 38 – Cumulative TCO over five years for different scenarios of Uber vehicle ownership and operation



Given the initial higher CAPEX of the EV and the CP installation, the EV remains the more expensive option in the first two to three years of its lifetime.

Figure 39 – Breakdown of five year TCO for New ICE – outright purchase and New EV – Home CP – outright purchase scenarios

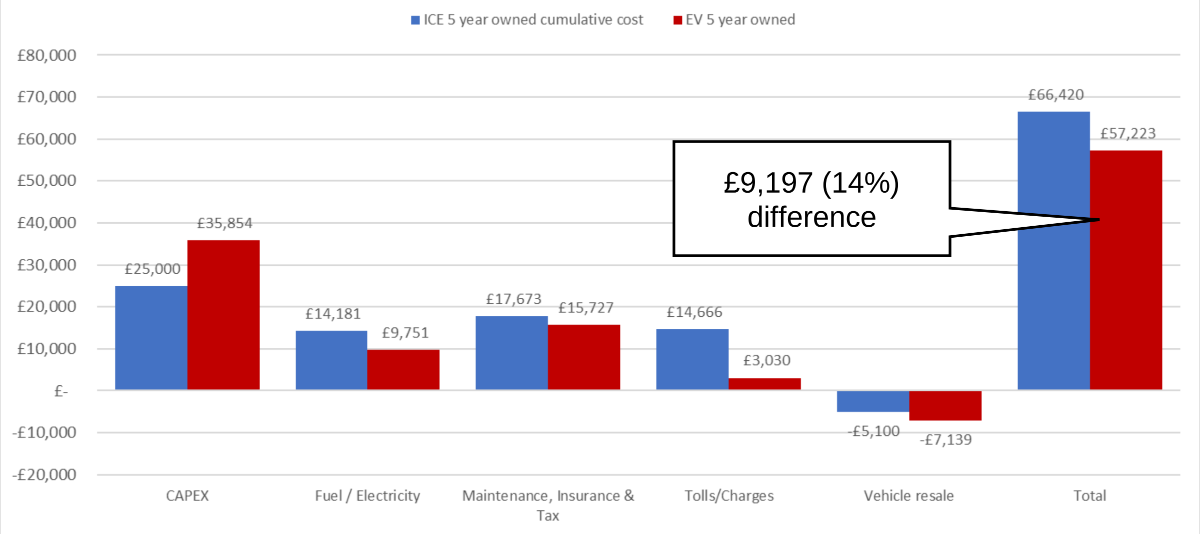


Figure 39 shows the breakdown of costs over five years comparing the outright purchase scenario of a new ICEV vs. a new EV with a home CP. Tolls and charges represent the largest difference, due to the exemption of EVs from the London Congestion Charge Zone until the end of 2025. Assuming calculation start at the beginning of 2022, the benefit accrues over the first four years of EV ownership. Despite a higher initial investment, this difference in tolls is what creates most of the five year TCO advantage for the EV in this case.

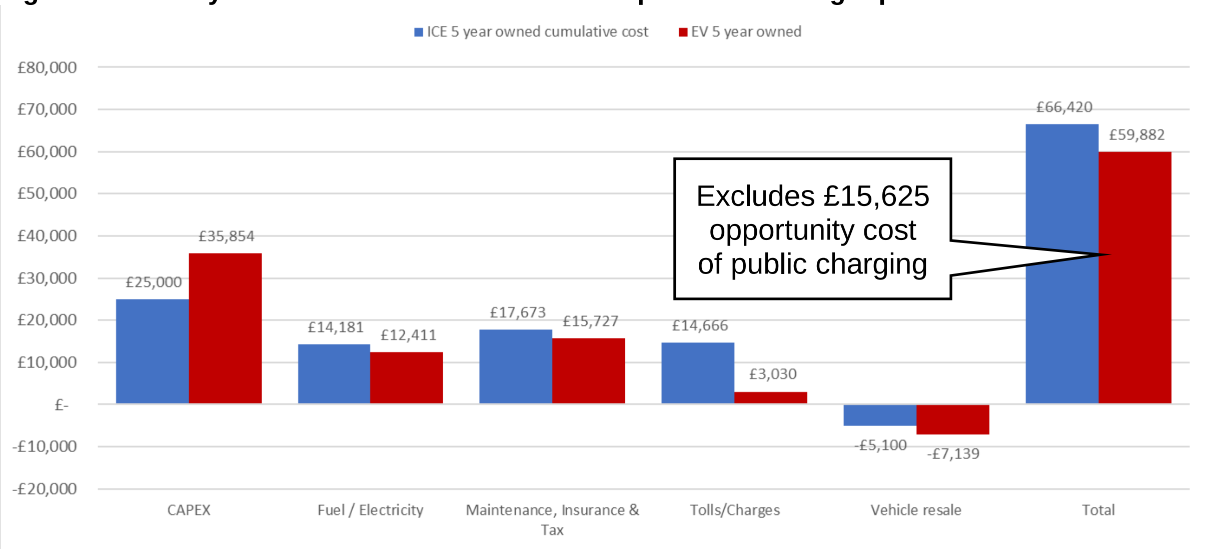
Despite a rise in electricity costs in 2022, the EV remains cheaper to run. This is based on a public charging cost of 35p/kWh and a home charging cost of 25p/kWh. The difference in fuel costs is thus the second highest in the five year TCO, creating savings of £886 per year.

Key learning: When comparing the outright purchase of a new EV and a home CP to a new ICEV over five years, the TCO for the EV is 14% lower despite the initial CAPEX being 30% higher. The higher CAPEX is offset by savings in congestion charges and running costs, resulting in a payback of two to three years for the EV compared to an ICEV. A leasing deal on the EV would offer more flexibility and reduce the initial CAPEX, but results in a five year TCO being 47% higher than outright purchase for the New EV – Home CP persona and 26% more expensive than an outright purchase of a new ICE.

3.4.3.2 Persona comparison: New EV – Public CP vs New EV – Home CP – outright purchase

The New EV – Public CP persona, shown in Figure 40, does not have off-street parking and so must charge on public CPs 100% of the time. A major difference in this scenario is therefore a higher overall electricity cost, up by 20% compared to the New EV – Home CP persona. The CAPEX is also affected by the CP installation costs. This signifies a reduction in the TCO gap between ICEV and EV outright purchase, now down to £6,538 over the five year period compared to £9,197 for New EV – Home CP persona.

Figure 40 – Five year TCO for New EV – Public CP persona – outright purchase



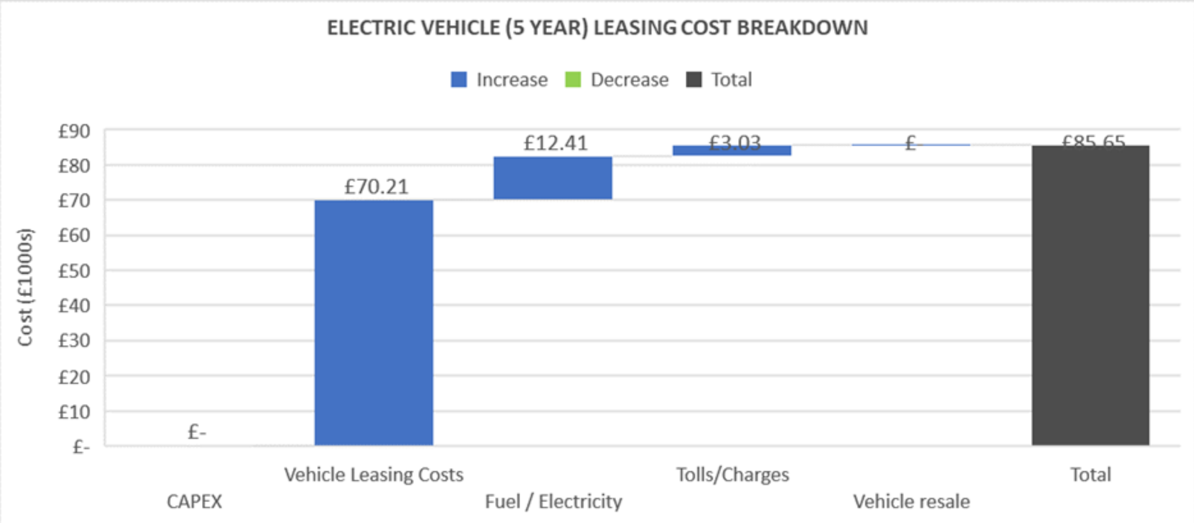
The time spent public charging while on shift also results in an opportunity cost of not accepting Uber trips, which has not been factored into the TCO model. The size of the opportunity cost changes depending on whether the driver is able to charge the EV overnight, on-street, near their home, or whether they rely entirely on the rapid charging network. In the latter scenario, the New EV – Public CP persona would top-up charge once per day, thus spending 45 minutes charging (c.30 minutes longer than a petrol stop), for a total opportunity cost of £15,625 over the five year TCO period, assuming an average hourly income of £25. This is reduced to £3,906 over five years if only some top-up charges are required (25% of the time).

Key learning: public charging reduces the TCO gap between ICEV and EV regardless of finance option but remains beneficial towards EV owners over the long-term. However, factoring in the opportunity cost of time spent public charging rather than driving can add as much as £15,625 over the five year period, tipping the TCO balance against EV. To reduce the opportunity cost, it is necessary for the public charging infrastructure to be easily accessible and reliable.

3.4.3.3 *Persona comparison: New EV – Public CP – Outright purchase vs. Leasing vs. Financing*

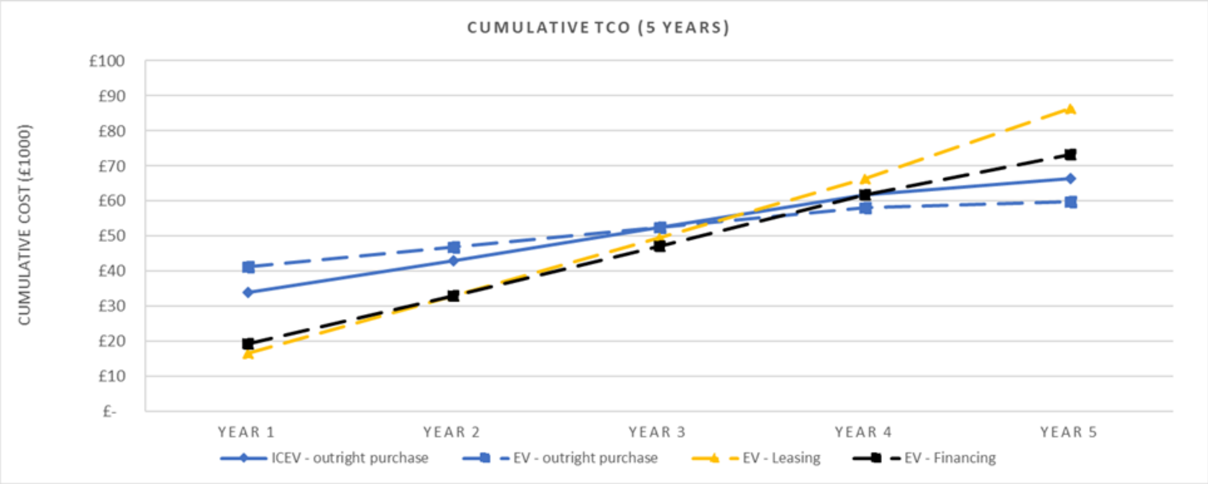
Many Uber drivers opt for leasing a vehicle rather than a cash purchase or financing option, to avoid a high initial investment and allow for flexibility on their contract. Most leasing companies also offer insurance, tax and maintenance included in the monthly lease price. This means a higher overall TCO, with a different split between fixed and variable costs: as seen in Figure 41, the vehicle leasing costs alone reach £70,200 over five years for the New EV – Public CP persona. This constitutes over 80% of the total TCO and represents a fixed monthly cost for Uber drivers regardless of their utilisation – which may be a barrier for drivers, whose income is variable and difficult to forecast. An advantage of a leasing deal is that it can usually be terminated early, offering some level of flexibility should the circumstances change.

Figure 41 – Five year TCO breakdown for New EV – Public CP persona – leasing



The financing option falls in between cash purchase and leasing: monthly repayments plus interest mean a higher TCO than the outright purchase, but lower than a leasing option, with a total TCO of £73,376 for the New EV – Public CP persona (see Figure 42 for comparison to other ownership models). This is a popular option for Uber drivers who have access to finance, as it allows a low CAPEX investment while gaining ownership of the vehicle after the repayments are made. At the same time, termination of financing arrangements usually attracts penalties, making it a less flexible option than leasing. The questionnaire analysis section discusses some of the difficulties for Uber drivers to access financing options for their vehicles.

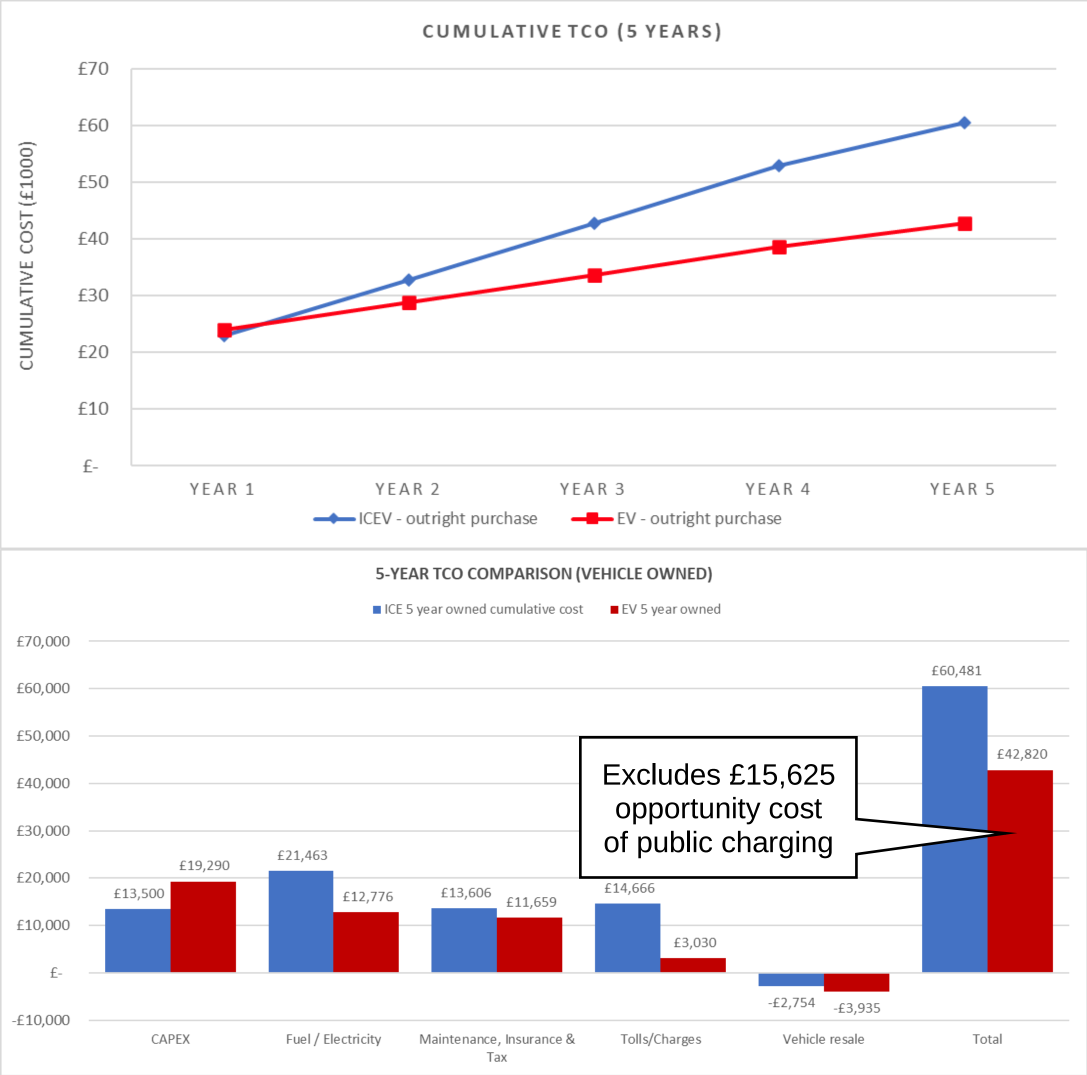
Figure 42 – Cumulative five year TCO comparison for New EV – Public CP persona outright purchase, leasing, and financing options



Key learning: Leasing and Financing are the most likely choice for PHV drivers switching to EVs. Despite the lower initial CAPEX, the high leasing and financing costs mean a higher five year TCO compared to an ICEV or an EV outright purchase.

The scenario analysed in Figure 43 is a comparison between Second-hand ICE purchase and Second-hand EV – Public CP. This like-for-like comparison would be ideal for Uber drivers, given the popularity of second-hand vehicles as a lower CAPEX option. However, the unavailability of used EVs suitable for PHVs is preventing rapid uptake from the drivers. The second-hand ICE is modelled as a Toyota Prius 2015 model, bought for £13,500, with related lower fuel efficiency of 5.6L/100km and lower vehicle resale value, as well as higher maintenance costs, but lower insurance. The second-hand EV is a Nissan Leaf 2018 bought for £19,290. When factoring in the opportunity cost of public charging, the EV TCO reaches £58,445, thus cancelling out the difference between the two TCOs.

Figure 43 – Cumulative TCO comparison between Second-hand ICE and Second-hand EV – Public CP outright purchase personas



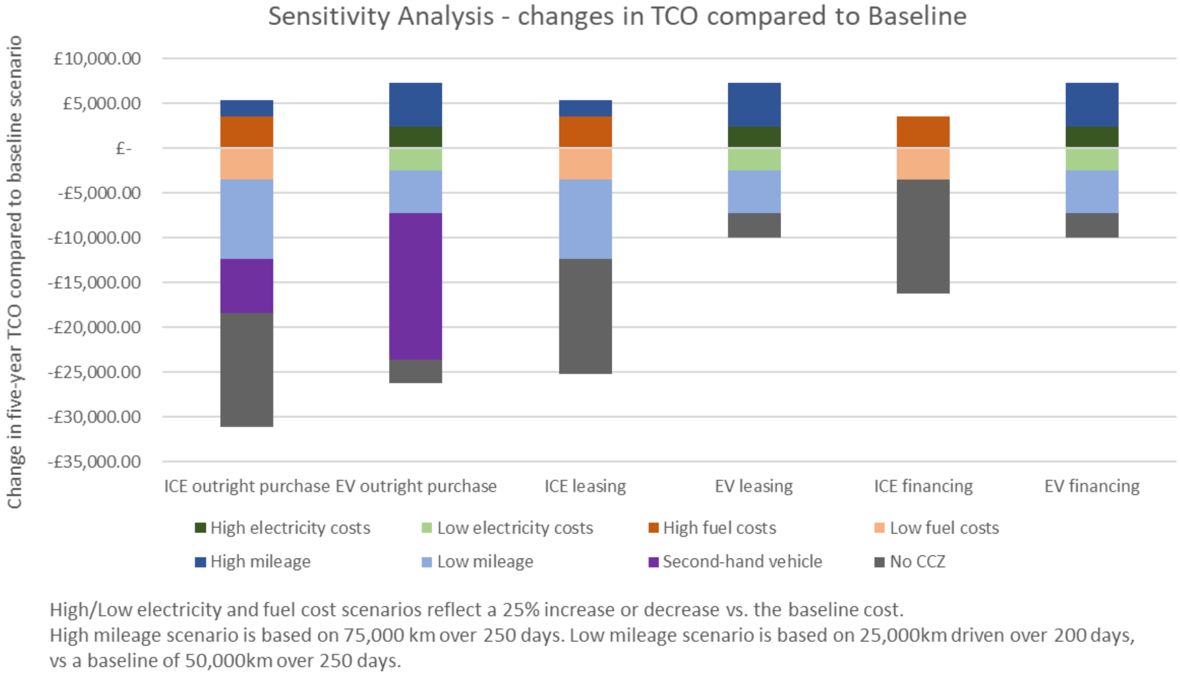
Key learning: this like-for-like comparison shows the potential of second-hand EVs in the PHV market: a lower CAPEX reduces the barrier to entry, while the payback on year one encourages more risk-averse drivers to make the switch. However, currently a lack of affordable second-hand EV options remains a barrier to achieve breakeven with non-EV models for the majority of PHV drivers. The opportunity cost of public charging shows the importance of reliable rapid CPs within the city.

The most likely scenario given the lack of available second hand EVs, comparing a second-hand outright-purchase ICEV and a leased new EV, shows a TCO of 30% higher for the New EV – Public CP driver.

3.4.4 Sensitivity analysis

The sensitivity analysis below (Figure 44) compares the five year TCO results for the different personas and scenarios covered in this report. Each scenario (second-hand, mileage, electricity costs, and congestion charge) has a positive or negative impact on each persona TCO. It should be noted that the graph illustrates the impact of each factor on the baseline independent of other factors. Some factors will be interdependent, for example the impact of fuel cost changes increases with higher mileage.

Figure 44 – Sensitivity analysis – TCO changes for different personas and scenarios, compared to their respective baselines

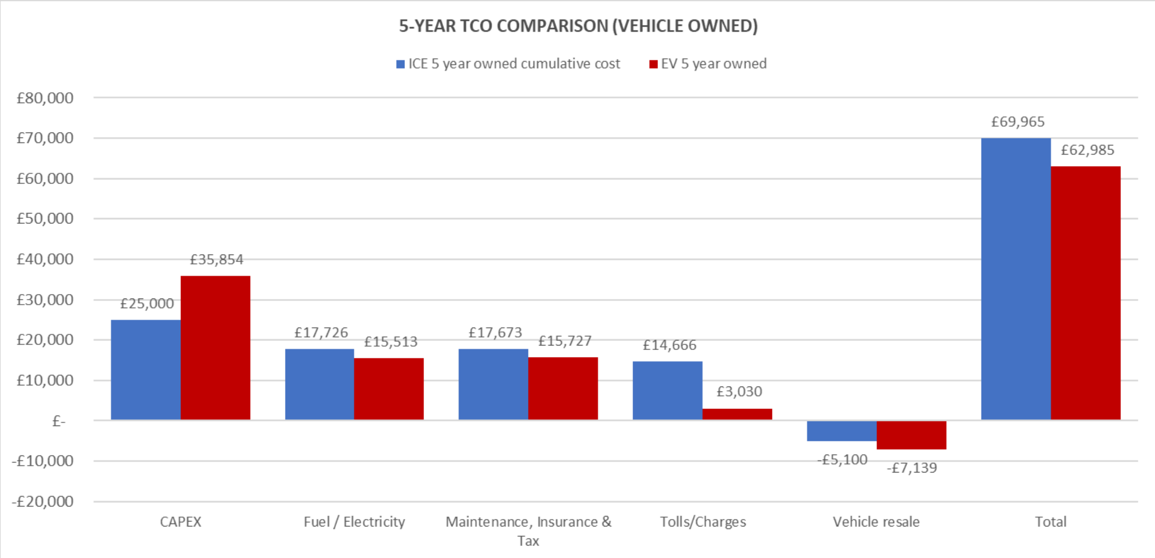


As expected, selecting a second-hand vehicle and driving fewer miles have the highest impact on the five year TCO. Second-hand vehicle purchase reduces the TCO by 9% on ICEV and 28% on EV outright purchases. The low mileage scenario reduces the TCO by 13% and 8% for ICEV and EVs respectively. The next highest TCO reduction is from lower fuel and electricity costs which reduce the TCO by 3-5% compared to the baseline scenarios. These findings reflect the fact that the highest cost components are the vehicle purchase price and the main operational costs of fuel and electricity.

3.4.4.1 25% higher fuel and electricity prices

The model is moderately sensitive to fuel and electricity prices. If electricity prices were to rise by a further 25%, this would increase the EV Public CP persona TCO by 5%. A 25% increase in fuel prices would have a marginally higher impact on TCO. The EV TCO remains lower than ICEV if both fuel and electricity priced increased by 25%, for all models of ownership (Figure 45) and in the outright purchase scenario the EV TCO would remain lower than ICEV TCO if electricity prices increased by 25% while fuel prices did not change.

Figure 45 – Breakdown of costs for 25% higher fuel and electricity price scenario (New ICE and New EV – Public CP personas (outright purchase))

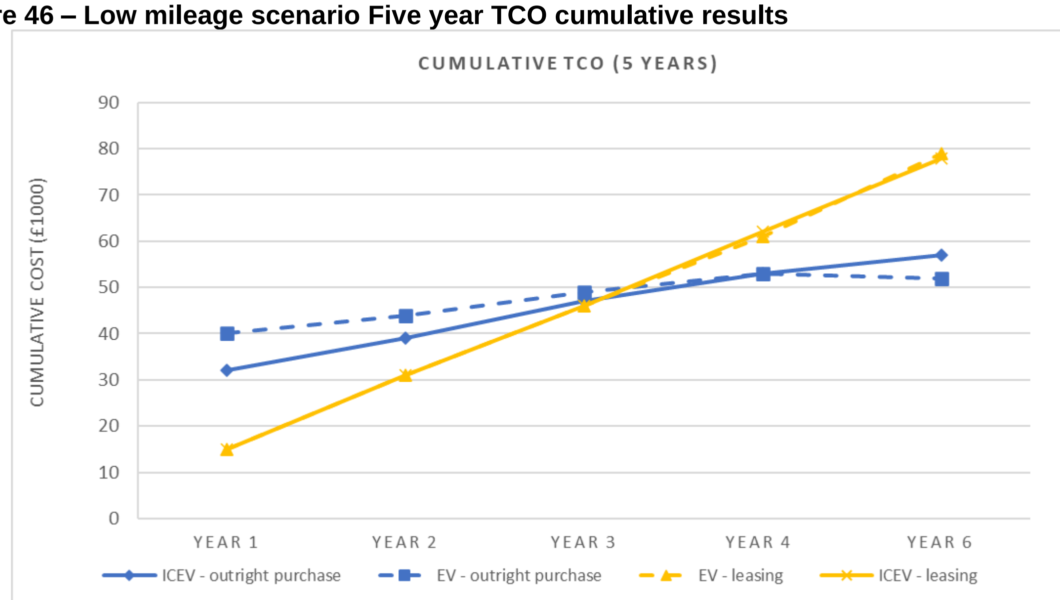


3.4.4.2 *Distance and days driven per year*

A change in kilometres driven per year is combined with a higher or lower number of days driven in central London within the Congestion Zone. This affects the toll costs section for petrol vehicles, with a high sensitivity towards the TCO.

The model is highly sensitive to kilometres driven per year. As the model excludes any revenue generated through Uber trips, a higher mileage will directly correlate to a higher TCO due to increased usage. However, the proportion of fixed and variable costs changes significantly, as fixed costs such as lease payments or insurance remain constant while fuel and electricity vary. Higher mileage also favours the EV TCO compared to the ICEV, as long as the difference between electricity and fuel prices remains constant or increases. At 25,000 km and 200 days of driving per year, the EV Public CP persona breaks even with the New ICE persona on year four (Figure 46). This can be an important consideration for PHV drivers when assessing their vehicle options.

Figure 46 – Low mileage scenario Five year TCO cumulative results



3.4.4.3 Congestion Charge Zone

At £15 per day, the congestion charge represents a significant cost for ICEV Uber drivers in London. Across the five year period, a non-EV driver could expect to pay nearly £15,000 in tolls if entering the Zone 75% of the operational days. EV drivers are exempt from the congestion charge, generating a significant saving compared to ICEV counterparts. However, this exemption is due to end in December 2025. For this reason, the EV TCO includes an element of congestion charge payments from January 2026 onwards.

In the sensitivity analysis results above (Figure 44), the "No CCZ" scenario symbolises a driver who rarely enters the congestion charge zone – only 25 days per year. In this case, the New ICE TCO is lower than the New EV – Public CP TCO regardless of the ownership model thanks to savings of £12,730 over the five years – a 19% reduction in TCO on the ICEV outright purchase, or 14% on vehicle leasing.

3.4.4.4 Vehicle Tax

Vehicle tax has less effect on the TCO model: ICEVs pay £140 in the first year of ownership, and £160 every year thereafter. EVs are currently exempt from Vehicle Excise Duty – meaning a saving of £793 (including inflation) over the five year TCO period.

Key learning: the congestions charge exemption is essential in reducing operational costs for EV drivers. Vehicle choice and second-hand vehicle availability will also play a crucial role in the TCO for EV PHV drivers.

3.4.5 Emissions analysis

The graphs in Figure 47 and Figure 48 display the cumulative and yearly carbon equivalent emissions comparing ICEV and EV, under baseline scenario conditions, for a single driver and vehicle. A timeline to 2030 was chosen in order to capture the reduction in EV charging emissions based on the National Grid's electricity generation mix.

Figure 47 – Cumulative CO2e operational emissions from vehicle use

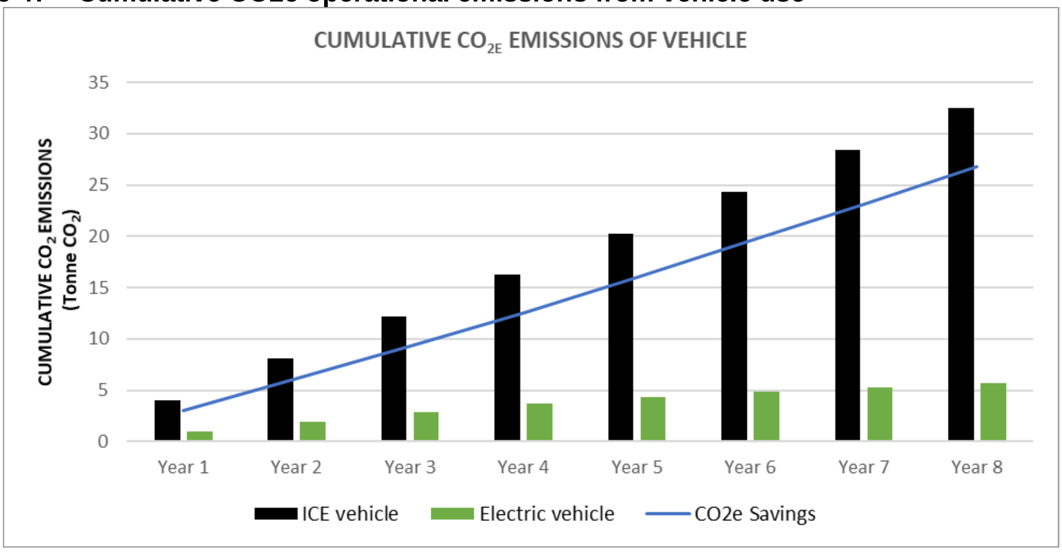
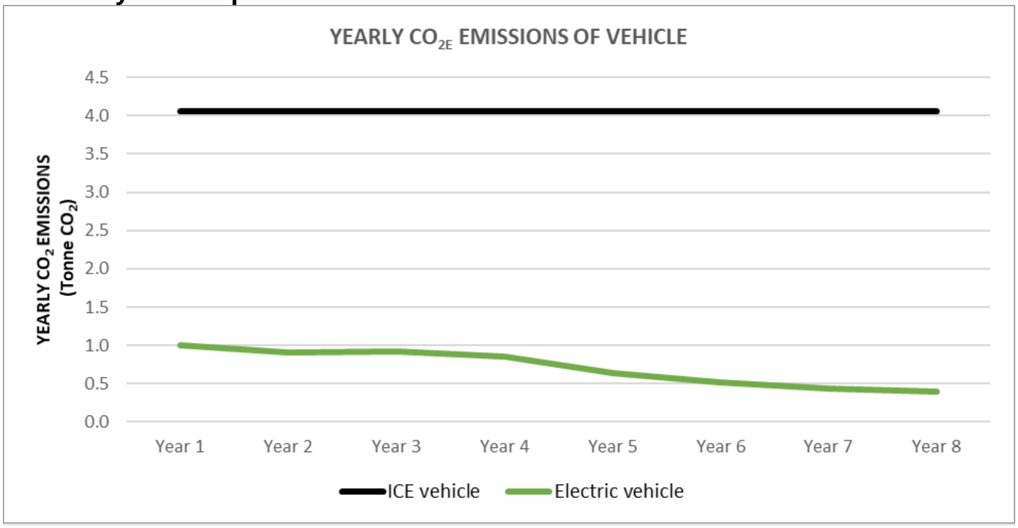


Figure 48 - Yearly CO2e operational emissions from vehicle use



ICEV yearly emissions remain stable until 2030, at around four tonnes of CO2e, reflecting the direct link between petrol usage and vehicle emissions. EV usage emissions are more complicated and variable, as they reflect National Grid's emissions from electricity generation. As seen in the chart above, EV yearly emissions from electricity use are predicted to decrease from a baseline of one tonne of CO2e to 0.45 tonnes in 2030, based on National Grid's Future Energy Scenarios. Over the five year TCO period, the difference in emissions between the ICEV and EV will be of 16 tonnes of CO2e given 250,000km driven.

3.4.6 Key learnings from the Mixed-fleet TCO

The outlook on the Uber TCO is encouraging, with most like-for-like scenarios leading to a lower five year cost for EVs compared to ICEVs despite a higher vehicle cost. However, a lack of affordable and available second-hand EV options remains a barrier to achieving breakeven with non-EV models for the majority of PHV drivers.

The congestion charging exemption for EVs plays a crucial role in the breakeven point between the ICEV and EV TCO

The cost savings seen in the EV TCO are mostly from the exemption from the London congestion charging zone and the lower operational costs: the hard stop for the exemption in December 2025 lowers the operational benefits for EV significantly, cutting a key incentive for Uber drivers. Incentives on short-term leasing contracts for EVs could further lower the gap between the TCOs during the transition period to 2025, after which vehicle financing and second-hand options may become more affordable.

The limited availability of affordable second-hand EVs at present could be a barrier to some drivers

Some key comparison scenarios remain in favour of ICEV, the most important being the second-hand vehicles: this is a typical purchase for an Uber driver, and the lack of affordable second-hand EVs remains a barrier to achieving break-even with the ICEV models. This is likely to change over time as the market matures.

Opportunity cost of public charging tips the TCO against EV

Factoring in the opportunity cost of £15,625 for time spent public charging rather than completing trips leans the TCO balance against EV. To reduce the opportunity cost, it is necessary for the public charging infrastructure to be easily accessible and reliable.

Nuances in the decision-making process means not all drivers will place the same importance on TCO results

While this model is useful in comparing ownership costs between ICEVs and EVs in general terms, Uber drivers act as individual decision-makers: the rational TCO calculations displayed in this analysis may interest drivers of certain characteristics who are particularly sensitive to cost. However, as analysed in the behavioural questionnaire results, reluctance to switch to an EV is often not only a financial decision with nuances such as vehicle choice, range anxiety, and convenience involved.

Operational emissions analysis shows the clear environmental benefit for PHV drivers to switch to an EV

The operational emissions analysis showed the obvious benefit in switching to an EV for a high-mileage driver demographic (16 tonnes over 5 years). By 2030, emission reduction becomes increasingly marked as the grid energy mix transforms, headed towards Net Zero. Emissions considerations will also be relevant for Uber and other PHV organisations while transitioning to fully electric fleets.

3.4.7 Next Steps

Optimise Prime will explore the impact of smart charging of the EV. The home CP persona will be adapted to model the impact of smart charging on electricity costs over the TCO.

A whole-fleet view will also be explored to combine behavioural analysis, TCO and data science results to assess PHV charging behaviour.

3.5 Summary of Key Learnings from TCO analysis

Across the three project partners, the economic findings of the TCO approach yielded different results but also some common learnings:

At present, whether TCO favours EV or ICEV fleets varies considerably across and within the different use cases

EV prices are the key determinant of whether EVs make purely economic sense for a fleet, but there are many other factors influencing the cost, including connection costs for depots

The impact of electricity price rises relative to diesel costs is especially noticeable in fleets using public charging. Ongoing volatility in these costs are likely to continue to impact the accuracy of cost forecasts

Smart charging appears to be one of the best routes to improve TCO competitiveness, wherever possible, for depot or home-based fleets

The Congestion Charging exemption for EVs plays a crucial role in the breakeven point between the ICEV and EV TCO for a driver on the Uber platform, and significantly impacts other fleets operating in London

Operational emissions analysis shows the clear environmental benefit for PHV and fleet drivers to switch to an EV

3.6 Impacts on the distribution network

3.6.1 Introduction

The initial project business case described in Appendix 10.3 to the FSP stated "Optimise Prime will save GB DNOs and electricity customers £207m by releasing over 1,900 MVA of capacity on the distribution network by 2030". These savings estimates were based on assumptions regarding the value the methods trialled under Optimise Prime would be able to deliver.

Since the FSP submission, UK Power Networks have commissioned Element Energy to develop the Strategic Forecasting System (SFS), an integrated set of software tools that will enable improved forecasting of load growth on the networks under different scenarios and analysis of what this means for network operation and investment, over RIIO-ED2 and beyond. The SFS is fed by UK Power Networks' Distribution Future Energy Scenarios17 (DFES) and allows for high granularity of planning, down to Lower Layer Super Output Area (LSOA) level. It was decided that the SFS should be utilised as part of Optimise Prime and replace the more high-level approach to calculating the project's impact presented in the FSP. This will allow Optimise Prime to align the project's impact calculation more closely with UK Power Networks' DFES, and to ensure that enhancements to the SFS can be made using Optimise Prime's results in order to benefit future network planning efforts.

This activity involves working in collaboration with Element Energy to incorporate new data gathered by Optimise Prime on the behaviour of vans and PHVs into the SFS's EV modelling in order to:

- Estimate the volume of LV infrastructure requiring reinforcement
- Estimate a high-level cost of that reinforcement
- Calculate the demand (in kW) from relevant EV technologies at selected secondary substations
- Demonstrate how different approaches to managing charging behaviour trialled by Optimise Prime would change the reinforcement requirements and related costs.

The work was subdivided into two phases:

- Phase 1**:** Incorporating van/PHV behaviour datasets based on Optimise Prime's initial trial data and behavioural questionnaires collected up to the end of January 2022 into the current version of the SFS to produce an initial version of the first three above outputs. Phase 1 also enabled the project team and the SFS development team to refine and align their understanding of the trial outputs and SFS functionalities, to scope jointly what future SFS development can look like. This will ensure Optimise Prime's outputs are fully used to enhance the SFS.
- Phase 2**:** Introducing modifications to SFS that will allow the tool to better reflect the findings from Optimise Prime. This phase may require modifications to the tool's logic. The results of Phase 2 simulations will be based on the combined inputs from completed Optimise Prime trials and will be presented in the final project deliverable D7.

[17] https://www.ukpowernetworks.co.uk/future-energy/dfes-2022

3.6.2 Phase 1 – Inputs

3.6.2.1 Data inputs

The SFS takes the uptake scenarios developed in the DFES, allocates future customers and technologies to the UK Power Networks' distribution network and models the resultant impact upon demand and generation from the bottom up, through the network. In order to inform that modelling, the SFS must apply assumptions around the technological performance of low carbon technologies such as EVs as well as the behaviour of consumers owning those vehicles. Examples of assumptions required include distances driven, charging times and charging frequency. It is those assumptions within the SFS for vans and private hire vehicles that Optimise Prime set out to refine.

Hitachi provided Element Energy with the following datasets based on data gathered from the Optimise Prime trials, which were used to improve the SFS's modelling of the behaviour of vans and private hire vehicles:

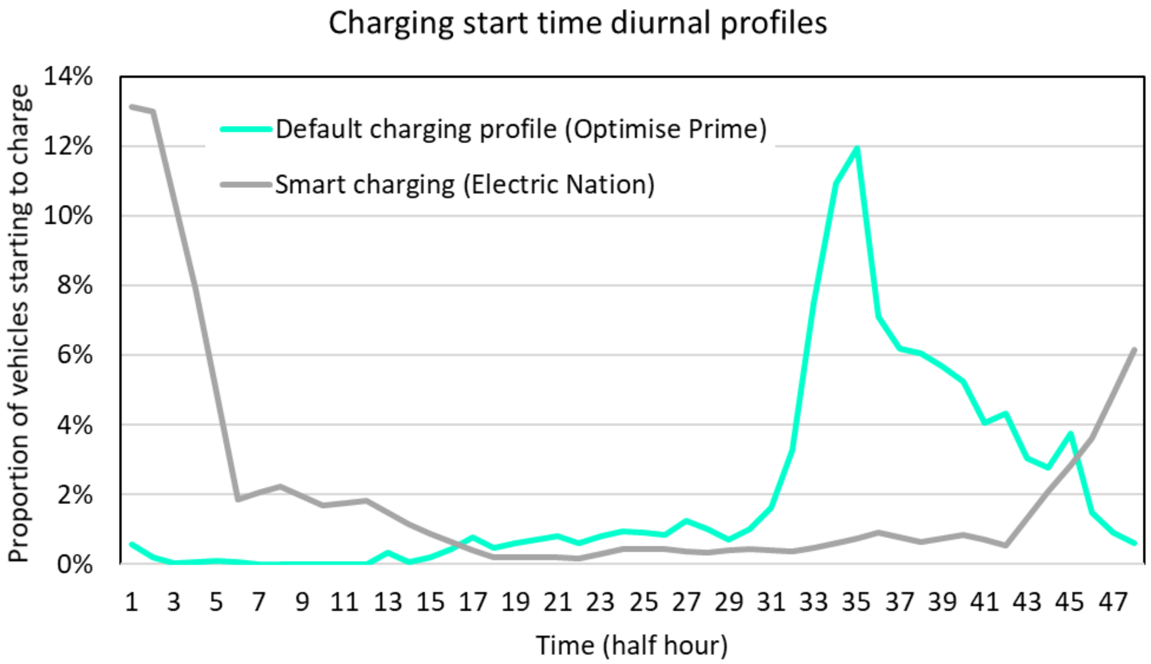
- Distance travelled per day, per vehicle (km) for each year out to 2050
- Charging frequency per vehicle per day (events/day) for each year out to 2050
- Charging location breakdown (% of energy obtained from home, work, enroute charging etc.)
- Charging rate at specific charging locations (kW)

Hitachi also provided plug-in start time diurnal profiles for vans and private hire vehicles (percentage of vehicles plugging in to charge in a given half hour period over the day) that were applied across the existing vehicle types in the SFS.

The SFS uses EV user archetypes to model charging behaviour in a granular fashion, specific to the behaviours of different types of vehicle user. In the SFS, vans and private hire vehicles are assumed to be used by a subset of these user archetypes (primarily urban commuters who have a mix of off-street and on-street parking). The Optimise Prime trials revealed a range of behaviours and vehicle user archetypes. In Phase 1, this trial data was mapped to the existing SFS archetypes based on the best match in vehicle archetype characteristics.

Figure 49 shows the resultant "standard" charging profile developed based upon the available Optimise Prime trial data. This profile is a weighted average of the charging behaviour of the vans and private hire vehicles, as those vehicles currently use the same charging profiles in the SFS. This profile clearly shows that the standard charging behaviour of the vehicles from Optimise Prime included in this dataset is dominated by charging in the early evening, with a peak of 12% of vehicles starting to charge in the half hour around 1800 hours. This is a common time for the existing peak on many parts of the distribution network; therefore, the electrification of vans and private hire vehicles could reasonably be expected to cause numerous constraints on the distribution network if this default charging behaviour were to be followed.

Figure 49 – Charging start time diurnal profiles for default electric vehicle charging behaviour (Optimise Prime data), and smart charging (Electric Nation data)



For contrast, the smart charging profile currently used in the SFS is also shown in Figure 49. This smart charging profile was developed in the Charger Use Study[18] based on Electric Nation trial data for delayed charging behaviour. This profile shows a much later charging start time, with ~13% of vehicles starting to charge around midnight. This behaviour clearly avoids the typical existing early evening peak on the distribution network; however, a lot of charging is still clustered in a narrow time window in the middle of night, which could lead to issues with the creation of secondary peaks.

3.6.2.2 Scenario assumptions

In order to investigate the impact of the electrification of vans and private hire vehicles on the distribution network, the SFS was run for three different scenario worlds (Table 32) using the new inputs from Optimise Prime detailed above. The 'Consumer Transformation' scenario from the DFES was selected as the "baseline" scenario, with all assumptions not relating to EVs applying the assumptions from the Consumer Transformation world[19]. Consumer Transformation was chosen as the baseline as it was used as the central planning scenario in UK Power Networks' RIIO-ED2 Business Plan.[20]

In this work, new data from the Optimise Prime project was used, where available, to replace the modelling assumptions relating to EVs, particularly vans and private hire vehicles. Where data was not yet available from the Optimise Prime trial, the existing SFS modelling assumption were retained.

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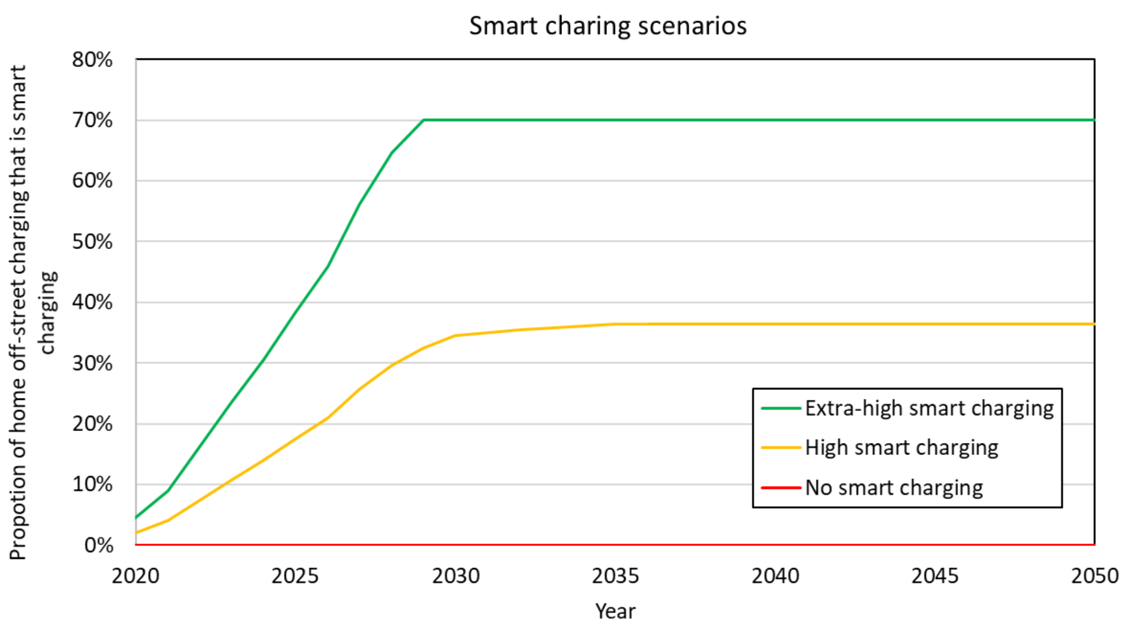
[18] UK Power Networks innovation – Charger Use Study 2018
[19] UK Power Networks Innovation - Distribution Future Energy Scenarios 2021
[20] UK Power Networks – ED2 Business Plan 2021

Table 32 – Scenario worlds run in the SFS for the Optimise Prime project

Scenario world	Scenario world basis (except EVs)	EV behavioural data	Smart charging scenario
Optimise Prime: Baseline	Consumer Transformation	Optimise Prime	High (CT)
Optimise Prime: No smart charging	Consumer Transformation	Optimise Prime	None
Optimise Prime: Extra high smart charging	Consumer Transformation	Optimise Prime	Extra High

The baseline Consumer Transformation scenario assumes that a 'high' level of smart charging uptake is achieved in future years (Table 32). Element Energy performed runs for two additional scenarios aside from the baseline scenario: 'no smart charging' and 'extra high smart charging', to assess the impact of differing amounts of smart charging behaviour on network reinforcement requirements. The only parameter varied between the three scenarios was the degree of smart charging uptake; the difference in smart charging between the three scenarios is displayed in Figure 50.

Figure 50 – Smart charging uptake scenarios



Smart charging only applies to vehicles charging at "home" with off-street parking. It is worth noting that for vans, "home" is defined as the address at which the vehicle is registered and therefore includes workplaces. There is currently no smart charging assumed for those vehicles that charge on-street, at destination charging stations (e.g. supermarket car parks), nor at enroute rapid charging stations.

3.6.3 Phase 1 – Results

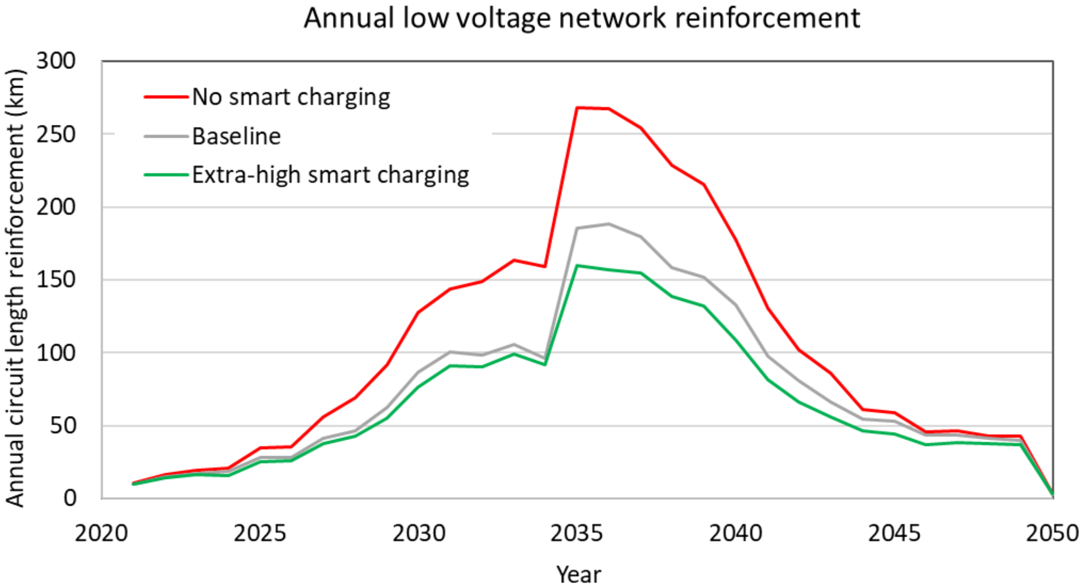
The SFS includes a load aggregation model and network constraint forecasting module that uses the load forecasts, generated by the load model component of the SFS, to identify future network constraints.

For the Optimise prime project, Element Energy and Imperial College London performed runs of the SFS across the low voltage network for all three of UK Power Networks' licence areas (London, South Eastern and Eastern Power Networks) using an updated version of the tool including the Optimise Prime trial data, as detailed in Section 3.6.2. Based on the expected loads for each customer connected to the distribution network, including any low carbon technologies such as EVs, the SFS calculates the expected load flow and resultant network reinforcement requirements year-on-year out to 2050. The model produces annual forecasts of upgrade requirements in terms of the length of low voltage (LV) network and the number of distribution transformers (in secondary substations) that will require upgrading in each licence area. Element Energy have aggregated these results across all three licence areas to produce summary charts of the forecast impact on network infrastructure.

3.6.3.1 LV network reinforcement

The SFS models the length of LV network cable requiring upgrades in each year based on the modelled expected loads for customers and low carbon technologies connected to each LV feeder. The results presented here are focussed on the reinforcement driven by thermal constraints due to load growth on the LV network. Figure 51 below shows the total length of LV cable requiring upgrade in each year, for the three different scenarios investigated as part of this project.

Figure 51 – Annual low voltage network reinforcement due to thermal constraints for the three Optimise Prime scenarios for UK Power Networks' three licence areas



The Consumer Transformation scenario, which is the basis for all three scenarios worlds shown in Figure 51, is a high electrification world. It includes significant electrification of transport, with no new fossil fuel passenger vehicles sold by 2035, leading to a steady increase in network constraints across the 2020s and early 2030s. Consumer Transformation also employs electrification as the main pathway for the decarbonisation of heating, with the widespread roll out of heat pumps. A ban on the installation of new natural gas heating systems leads to the step change in reinforcement seen in Figure 51 in 2035 as gas boilers at the end of their lifetime are instead replaced with heat pumps.

UK Power Networks' high confidence forecast best aligns to the DFES Consumer Transformation scenario, which delivers a Net Zero pathway with lower costs than alternative pathways. As part of the RIIO-ED2 business planning process, UK Power Networks also tested a range of other possible future scenarios. The distribution network impact results presented in this section for the RIIO-ED2 period (2023-2028) are aligned with the scenarios tested by UK Power Networks and published as part of their RIIO-ED2 business plan. The Baseline scenario shown here is aligned to the Consumer Transformation results from the Business Plan, while the Extra-high smart charging scenario is also very similar across the RIIO-ED2 period. Meanwhile the No smart charging scenario results are comparable to the Highest scenario tested as part of the RIIO-ED2 planning, which also looked at what the impact of low smart charging might be on network reinforcement requirements.

The electrification of transport could be a significant driver for network reinforcement; Smart charging has the potential to reduce this impact

Figure 51 demonstrates that the electrification of transport could be a significant driver for network reinforcement, with the "No smart charging" scenario exhibiting particularly high reinforcement volumes. However, Figure 51 also clearly highlights the potential value of smart charging in reducing the impact of EV charging on the distribution network, with the Baseline and Extra-high smart charging scenarios having much lower network reinforcement requirements due solely to a higher proportion of EVs charging outside of peak times.

The impact of smart charging is non-linear in the current models; Secondary peaks are likely to reduce the impact of very high levels of smart charging

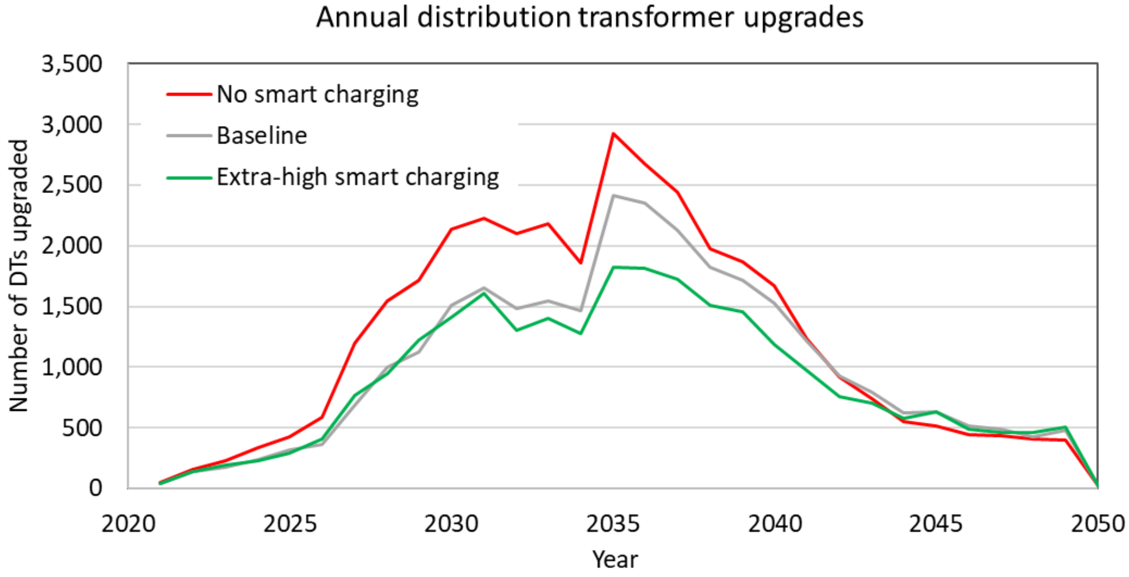
From Figure 51 it is also clear that the impact of smart charging is non-linear; with the difference in reinforcement volumes being much higher between the No smart charging and Baseline scenario worlds, than between the Baseline and Extra-high smart charging scenarios worlds, despite the increase in smart charging uptake between the two being similar (Figure 50). The likely explanation for this is the development of secondary peaks in the middle of the night due to the peaky nature of the smart charging profile (Figure 49). This conclusion is supported by the observation that post-2035 the Extra-high smart charging world shows a greater differential to the Baseline world. This greater differential is likely due to the electrification of on-gas heating from 2035 leading to higher evening peaks; thereby, reducing the impact of overnight secondary peaks and increasing the value of smart charging. This observation demonstrates that both the magnitude of network reinforcement and the value of EV smart charging is a complex interplay of the different loads connecting to the distribution network. It is planned to investigate this question in more detail in Phase 2 by investigating how different smart charging profiles might reduce the impact of secondary peaks, and thereby provide even greater value to the distribution network.

In Phase 2 the project will also delve further into the value that can be provided specifically from the smart charging of vans and private hire vehicles. The plots in Figure 51 include the impact of smart charging of all passenger vehicles that are smart charging in their “at home” location with off-street parking. Most notably, this include private passenger cars, which given they are considerably more abundant than vans and private hire vehicles, would be expected to dominate the charging load. However, both vans and private hire vehicles can have significant mileages, leading to higher impact on the distribution network per vehicle. As a result, preliminary analysis of the SFS results suggests that around 20-25% of the reinforcement avoided by increased smart charging in Figure 51 is due to the smart charging of vans, with a further 3% due to the smart charging of private hire vehicles. These figures indicate that collectively these vehicle segments are likely to represent a significant proportion of future charging load on the distribution network and have the potential to deliver considerable savings in terms of avoided network reinforcement if they are able to charge more flexibly.

3.6.3.2 Distribution transformer upgrades

The SFS also produces a list of all distribution transformers requiring upgrades for each future year out to 2050, as seen in Figure 52 below. For these results, the upgrades assume that a "one touch" approach to network reinforcement is applied, so a given transformer will only be upgraded once, assuming that it will be upgraded such that it is able to accommodate all future load growth. As with the LV network reinforcement, from Figure 52 it can be seen again that smart charging behaviour delivers a significant reduction in the number of transformers requiring upgrade in the near and longer terms: just over a third of upgrades could be avoided in 2028 if smart charging behaviours are employed as per the 'Baseline' scenario. In the late 2030s, the 'extra-high' smart charging uptake scenario could even deliver 500 fewer transformer upgrades annually compared to the 'Baseline' scenario.

Figure 52 – Annual distribution transformer upgrades for the three Optimise Prime scenarios for UK Power Networks' three licence areas



3.6.4 Next steps

The analysis performed in Phase 1 has revealed the considerable impact that the electrification of vans and private hire vehicles could have on the distribution network. The initial results also clearly demonstrate the significant value that smart charging of those vehicles could deliver in terms of avoided network reinforcement requirements. Both of those questions will be investigated in more detail in Phase 2 of this work.

In particular, the next steps for network impact modelling in Phase 2 will include the following:

- Implementation of the modifications to the SFS tool identified during Phase 1 in order to better reflect the findings of Optimise Prime.
- Revision of inputs/assumptions in light of learnings from the complete set of Optimise Prime trials.
- Conversion of avoided reinforcement volumes into estimated monetary benefits of smart charging.
- Extrapolation of the estimated benefits of Optimise Prime methods from UK Power Networks' licence areas to GB-wide benefits.

4 Behavioural Findings

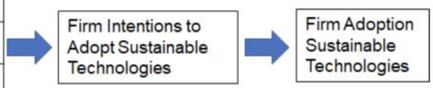
4.1 Methodology

The purpose of the behavioural research is to understand the decision-making process for fleet electrification and the factors that play a role in the speed of adoption. Combined with the quantitative data from the vehicles and CPs, additional qualitative data on the behaviour of the various stakeholders can provide insights into future adoption across commercial fleets and the potential impact on distribution network operators. The behavioural component of the Business Modelling workstream addresses research questions on adoption, barriers and enablers, user experience and changes in this experience over time, the impact of power networks constraints, and the organisational decision-making processes.

A literature review and meta-review was conducted by Imperial College Consultants to develop a set of 10 factors that determine the behavioural intent to adopt an EV, including perceived risk, management involvement, performance expectations and environmental and organisational factors. These were formalised in the Firm Adoption of Sustainable Technologies (FAST) framework[21]. Respondents were asked to rate several statements and were evaluated on a seven point Likert scale, from ‘Entirely Agree’ to ‘Entirely Disagree’, as shown in Figure 53. The questionnaires were designed with this framework in mind, building on earlier recommendations from Imperial College Consultants

Figure 53 – Fast Adoption of Sustainable Technologies (FAST) Framework

Construct	Definition
Perceived Risk (PR)	Firm perception of uncertainty plus the seriousness of outcome involved.
Management Involvement (MI)	The ability of firm managers to convince and explore effective ways to engage employees in using a new sustainable technology.
Training for Innovation (TI)	Information, knowledge, and skills enhancing a firm's understanding and technical readiness for the adoption of a specific sustainable innovation.
Performance Expectancy (PE)	Factors affecting a firm's beliefs that using a new sustainable technology will help attain performance gains.
Effort Expectancy (EE)	Factors hindering a firm's ease of use of a new sustainable technology.
Social Influence (SI)	The degree to which a firm perceives that the social context influences it to use a particular sustainable technology.
Environmental Factors (EF)	Factors external to the firm, such as government regulations and the industry in which a firm conducts its business.
Organisational Factors (OF)	Characteristics and resources of the firm, such as firm size, managerial structure and organisational slack.
Attitude	Managers' and employees' positive or negative feelings about adopting a new sustainable technology.
Emotions	Managers' and employees' collective emotional reactions towards the adoption of a sustainable technology.



4.1.1 Questionnaire design

The FAST Framework is the foundation for the selection of questions that have been included in five to 15 minute questionnaires, intended for different stakeholder groups.

The questionnaires vary between partners, due to sponsor discretion, and after taking into account previous findings. They also vary depending on the subject's seniority level. The aim was to collect data from EV drivers, fleet managers, senior managers and other key

[21] Mohammed, L., Niesten, E., & Gagliardi, D. (2020). Adoption of alternative fuel vehicle fleets–a theoretical framework of barriers and enablers. *Transportation Research Part D: Transport and Environment*, *88*, 102558.

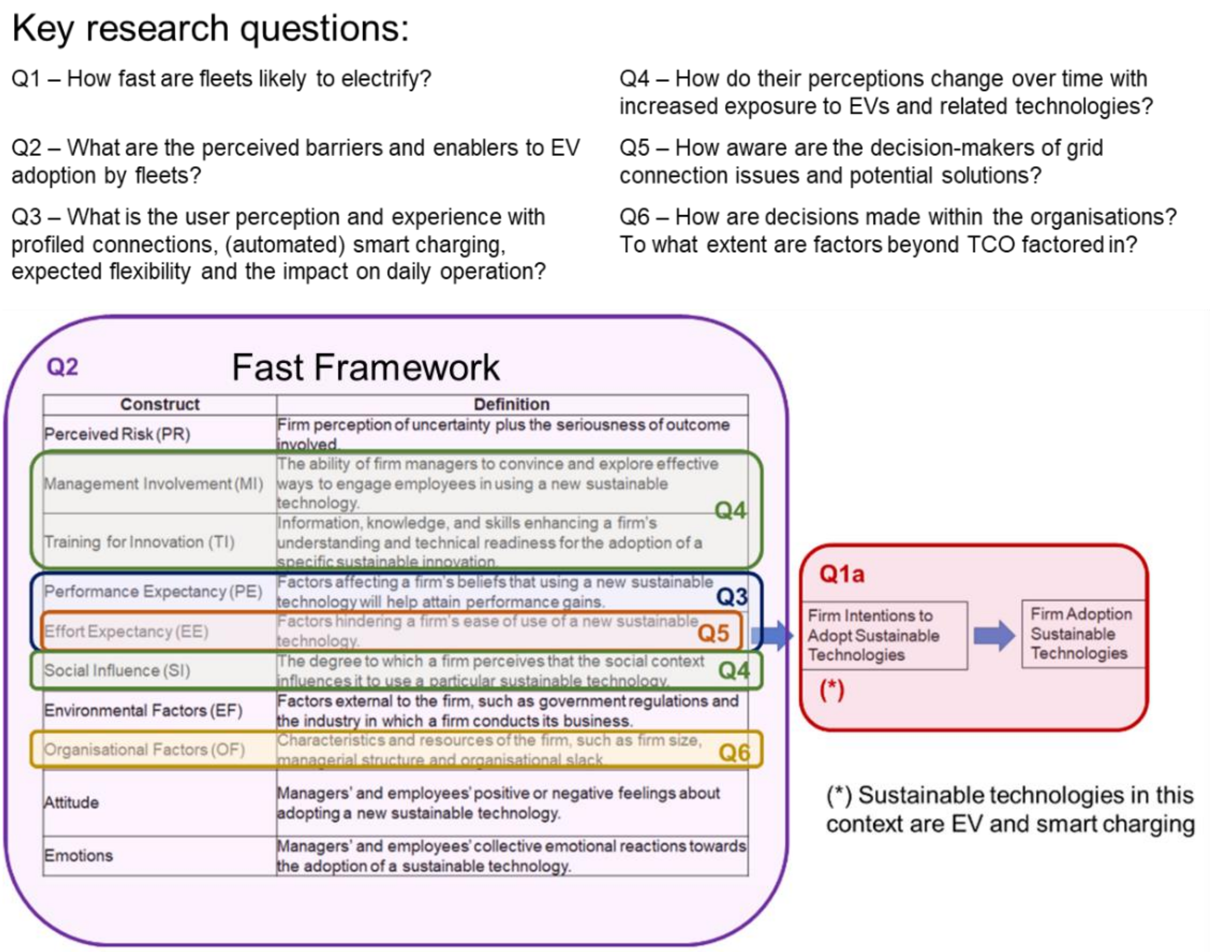
stakeholders, to understand their experiences and attitudes, and the impact of these on the decision to electrify their fleets.

The aim of this behavioural component is to support answering the following questions:

- How fast are fleets likely to electrify?
- What are the perceived barriers and enablers to EV adoption by fleets? This could relate to vehicles, charging infrastructure and software (charging controls, optimisation), as well as business strategies and (internal) communication.
- What is the user perception and experiences with smart charging, expected flexibility, and the impact on their daily operation?
- How do their perceptions change over time with increased exposure to EVs and related technologies?
- How aware are the decision-makers of network connection issues and potential solutions?
- How are decisions made within these organisations? To what extent are factors beyond total-cost-of-ownership factored in?

Figure 54 shows the mapping of FAST Framework's constructs onto the key research questions.

Figure 54 – Key Research Questions mapped onto the FAST Framework



The surveys included: 30 statements for Centrica, 26 statements for Uber and 19 statements for Royal Mail. Table 33 shows the link between the statement presented during the survey, which the respondents shared their opinion on, and the theoretical FAST Framework. For example, the "electric vehicle performance" factor is not tested directly, but respondents share their views on statements PE1-PE6. The survey was designed on the hypothesis that these are relevant factors, based on academic literature and previous research projects. The factor analysis, presented in Section 4.3, carried out by Imperial Consultants on the collected data, aims to confirm that the statements can be combined in a meaningful way and identify what these factors are.

Table 33 – FAST framework constructs and survey statements, with item identifiers

FAST Framework	Item	Statements
Management involvement and training	MI1	Our shift to electric vehicles is supported by sufficient information and training provided by our organisation
	MI2	Our managers are implementing strategies and technologies to ensure that the switch to electric vehicles has minimal impact on our tasks
	MI3	Uber's efforts to encourage the switch to electric vehicles is well received
Organisational structure	OF1	Drivers' inputs are considered when new vehicles, navigation technologies or other technological changes to are adopted by our organisation
	OF2	Drivers are consulted when new vehicles, navigation technologies or other technological changes are adopted by our organisation
Electric vehicle performance	PE1	Driving an electric vehicle is more pleasant as it is less noisy than a conventional vehicle
	PE2	The acceleration performance of the electric vehicles is very good
	PE3	The fact that the electric vehicle can be charged overnight saves working time, as it avoids fuel station trips
	PE4	On balance, an EV will be cheaper for me to drive over its lifespan
	PE5	Driving an EV will reduce my impact on the environment and air quality
	PE6	Overall, EV has/would improve my performance at work
Effort related to EV adoption	EA1	The limited range of electric vehicles makes/ would make it more difficult to fulfil my daily work tasks
	EA2	Long charging durations for electric vehicles are very impractical
	EA3	The limited availability of charging facilities at and around my home makes it more problematic to use an electric vehicle than a conventional vehicle for the fulfilment of my daily work tasks
	EA4	It is difficult to remember to plug-in the electric vehicle at the end of the shift
	EA5	Smart charging is risky - there may not be enough charge when the driver needs it
Attitudes/emotions & social influence	AI1	I am interested in electric vehicles
	AI2	I think electric vehicles would be beneficial to the environment in the long term
	AI3	I think that electric vehicles would eventually result in cost savings in my industry
	AI4	I think that electric vehicles are generally cool and pleasant to drive
	AI5	I think that electric vehicles are only a temporary phenomenon
	AI6	The range of electric vehicles is sufficient for most daily trips
	AI7	Free parking would make it easier to use electric vehicles
	AI8	It is advantageous to use electric vehicles because of the low energy cost
	AI9	Companies who have electric vehicles have good public image
	AI10	Companies within my industry are considering electric vehicles
	AI11	Electric vehicles are viewed favourably within my industry
	AI12	Business leaders in my industry are talking about switching to electric vehicles
	AI13	Policy makers expect companies in my industry to switch to electric vehicles
	AI14	Customers expect organisations in my industry to switch to electric vehicles
	AI15	I know fleet managers who are considering electric vehicles
	AI16	My customers prefer electric vehicles
	AI17	Smart charging saves British Gas money
	AI18	Overall, I support the rollout of smart charging across our electric fleet

4.1.2 Execution approach

To collect 'longitudinal' data and observe how attitudes change over time as more EVs are rolled out, the questionnaires were repeated at different stages of the project (see Table 34).

Table 34 – Number of responses by questionnaire iteration

	1st questionnaire iteration			2nd questionnaire iteration		
Organisation	Date	Total no. of responses	No. of responses from EV drivers*	Date	Total no. of responses	No. of responses from EV drivers*
Royal Mail	Jun-21	312	234	Feb-22	226	170
Centrica	Mar-21	108	19	Oct-21	230	86
Uber	May-21	798	71	Dec-21	952	388
Total		1,218	324		1,408	644

The execution methods varied by stakeholder group and project partner, as outlined below. Both, EV drivers and non-EV drivers were surveyed.

Royal Mail

- **Drivers:** paper printouts of questionnaires were distributed to drivers and questionnaires were conducted face-to-face. Questionnaires were anonymous, and so it was not possible to track individual opinion changes over time (it is possible to analyse data per depot)
- **Depot Managers:** on-line questionnaire completion via a Microsoft Forms link
- **Corporate Management:** on-line questionnaire completion via a Microsoft Forms

Centrica

- **Drivers:** on-line questionnaire completion via a Microsoft Forms link posted on an internal message board. No incentives were offered in the first iteration, £10 Amazon vouchers were awarded to all respondents in the second iteration
- **Senior Management:** on-line questionnaire completion via a Microsoft Forms link distributed via e-mail to relevant stakeholders, interviews with the Fleet Manager

Uber

- **Drivers:** on-line questionnaire completion via a Microsoft Forms link distributed via an internal newsletter. £10 Amazon vouchers were offered to selected respondents (those who were first to respond in the first iteration and randomly selected respondents in the second iteration). In the second iteration, EV drivers were targeted via a separate e-mail reminder to increase the response rate from this group.

The Uber drivers are the key decision makers in the context of EV adoption. While Uber offers incentives to transition to EV, it is the individual drivers who decide whether switching to EV is appropriate for them. The views of Uber's management were sought to help formulate the questionnaire questions and to interpret the results.

On-line questionnaires were conducted with selected customers of Novuna (formerly Hitachi Capital Vehicle Solutions) in order to confirm applicability of the survey findings to a wider range of fleets. The initial results of this analysis are presented in Section 4.4.

A seven point Likert scale was used in questionnaire questions that asked the respondents to rate their agreement with presented statements. For presentation purposes, a five point scale is used, with the categories mapped as shown in Table 35. Also, graphs show the impartial respondents on the disagreement side, and so the respondents who are presented as agreeing with the statement expressly stated a level of agreement.

Table 35 – Seven point agreement/disagreement Likert scale mapping onto a five point scale

Questionnaire scale	Presentation scale
Entirely Disagree	Entirely Disagree
Mostly Disagree	Disagree
Somewhat Disagree	Disagree
Neither Agree Nor Disagree	Impartial
Somewhat Agree	Agree
Mostly Agree	Agree
Entirely Agree	Entirely Agree

4.2 Fleet-specific learnings from behavioural study

4.2.1 Royal Mail

4.2.1.1 Overview and context

In the first iteration of the Royal Mail questionnaire, 333 participants responded to the questionnaire (312 drivers, 15 depot managers and six corporate managers). Drivers' responses were collected from nine London depots: Dartford, Whitechapel, Camden, Victoria, Premier Park, Orpington, Islington, Bexleyheath and Mount Pleasant. In the second iteration of the Royal Mail questionnaire, 231 participants responded to the survey (226 drivers and five depot managers). Driver's responses were collected from eight depots: Dartford, Whitechapel, Victoria, Premier Park, Orpington, Islington, Bexleyheath and Mount Pleasant. Additional results from Camden and other depots will be included in the final deliverable: D7. Table 36 below shows the numbers of EVs and CPs in each depot at the time of data collection, as well as the overall number of vehicles.

Table 36 – EVs and CPs at each depot at the time of the surveys

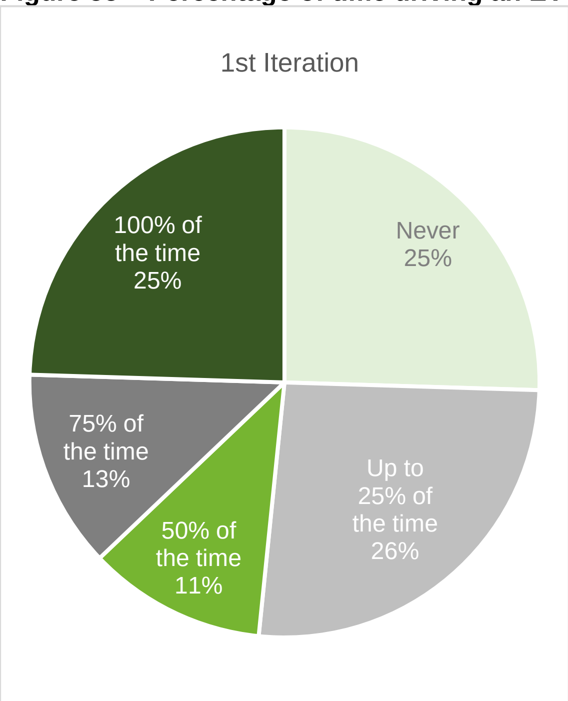
	June 2021 (1st iteration)		February 2022 (2nd iteration)		Total number of vehicles (EV & ICEV)
Depot	No. of EVs	No. of CPs	No. of EVs	No. of CPs	
Camden	6	3	12	3	37
Victoria	6	3	12	3	12
Orpington	9	3	12	3	28
Dartford	15	12	25	12	128
Bexleyheath	12	3	12	3	23
Islington	24	14	24	14	38
Mount Pleasant	87	47	123	47	192
Premier Park	47	27	49	27	111
Whitechapel	32	18	32	18	36
Total	**238**	**130**	**301**	**130**	**605**

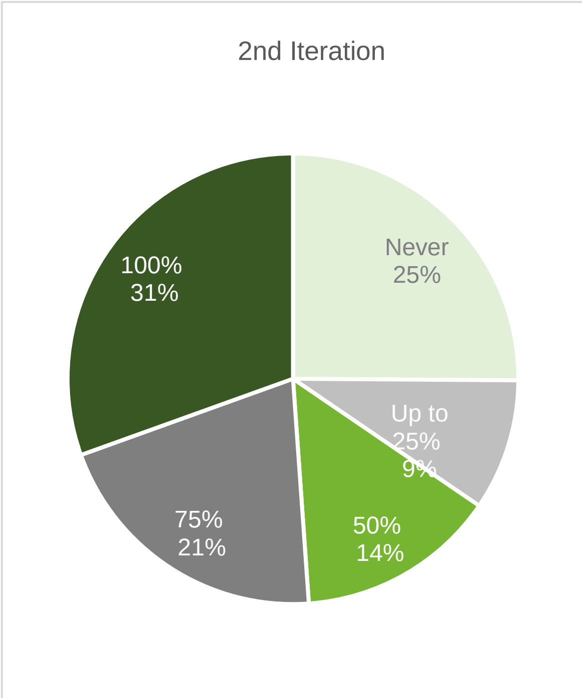
4.2.1.2 Drivers' questionnaire results

4.2.1.2.1 EV use behaviour

Royal Mail does not assign vehicles to drivers, and so a driver may drive an ICEV on some of the days and an EV on others. Vehicles are often allocated on a 'first come, first served' basis, with some drivers choosing ICEV or EV based on personal preference. At the time of the first and second questionnaire not all drivers had been trained to drive an EV . However, the majority of respondents (75%), during both rounds of the questionnaires, had some experience with EVs, with a quarter driving exclusively an EV during first iteration, increasing to 31% during the second iteration (see Figure 55).

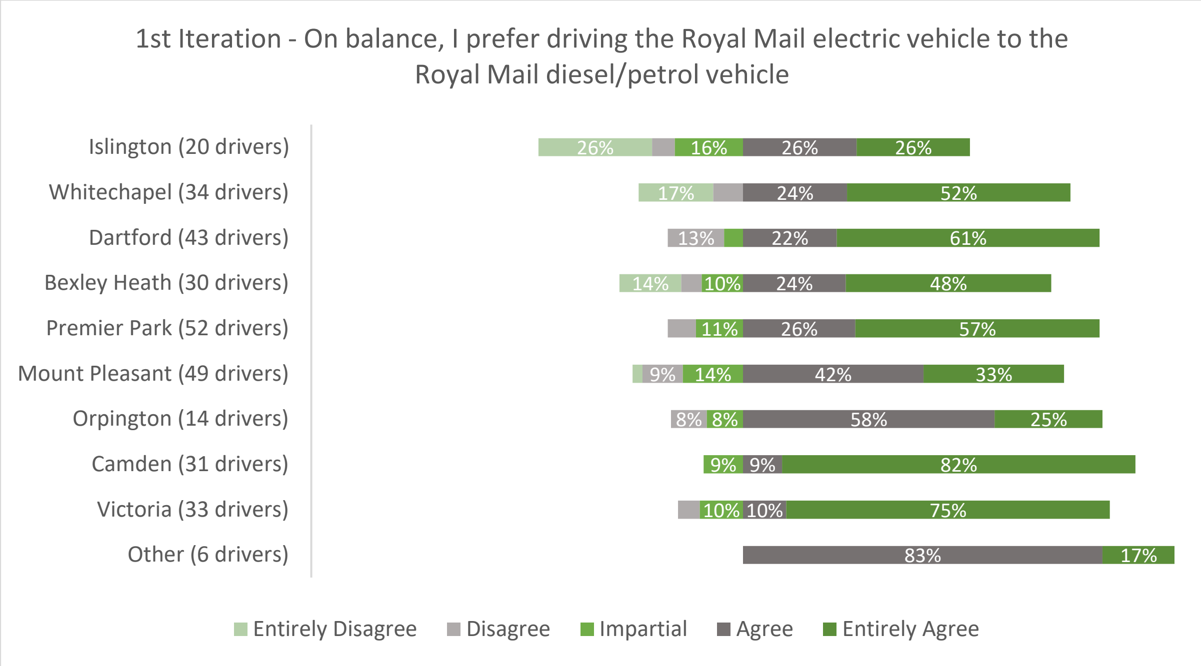
Figure 55 – Percentage of time driving an EV

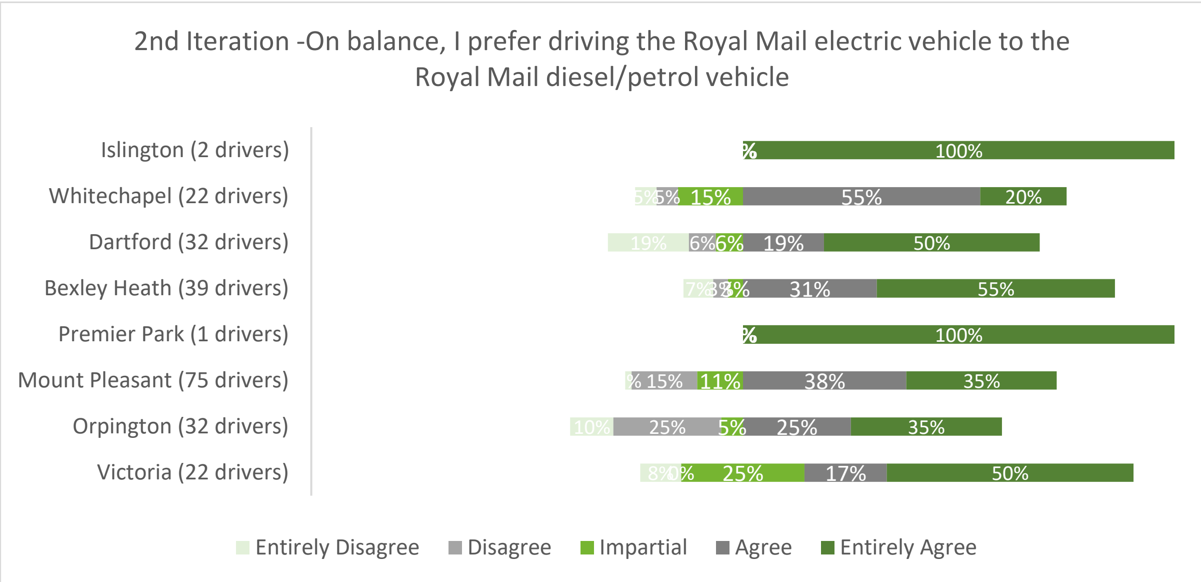




As shown in Figure 56 from both iterations of the survey, drivers across all depots preferred driving the EVs to ICEVs. However, in the first iteration, Islington stands out as an outlier with 26% entirely disagreeing with the statement and only 52% preferring to drive an EV. It is not clear why the views at Islington were different from the others. No issues with the EVs or the charging infrastructure were reported around the time of the questionnaires that could explain the negative perceptions. The results from the second iteration were less aligned: both Dartford and Orpington depot present a high percentage of disagreement with the statement. For Dartford this is 25% out of which 19% entirely disagree and for Orpington this was combined 35%.

Figure 56 – Driver preferences on driving an ICEV vs. an EV van





EV Drivers and Non-EV drivers reported similar distances driven during the first and second round of the survey. The majority of the drivers drive between 10-15 miles on a typical shift (Figure 57) with most driving less than 20 miles on a given shift (Figure 58). Telematics data (24/02/21 – 22/05/21) from seven of the nine Royal Mail depots shows that EV drivers typically drive 12.1 miles, compared with non-EV drivers at 18 miles per shift. The telematics data may include delivery and collection, explaining why it is higher than the typical distance reported by the drivers.

Figure 57 – Mileage distribution during given shift

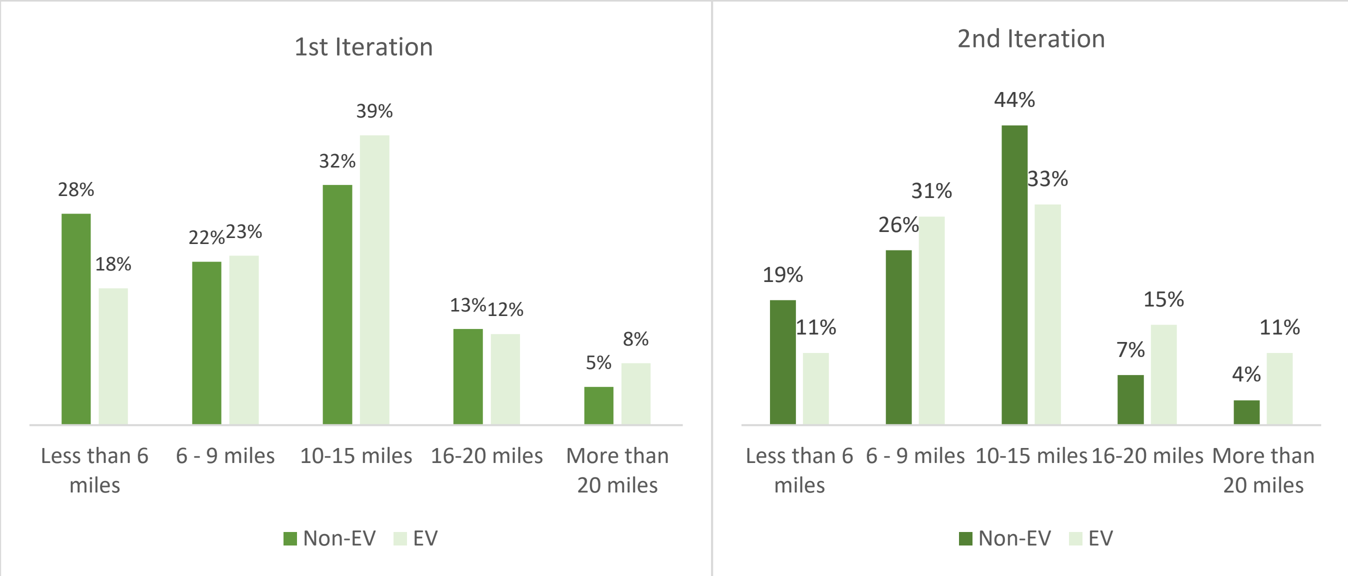
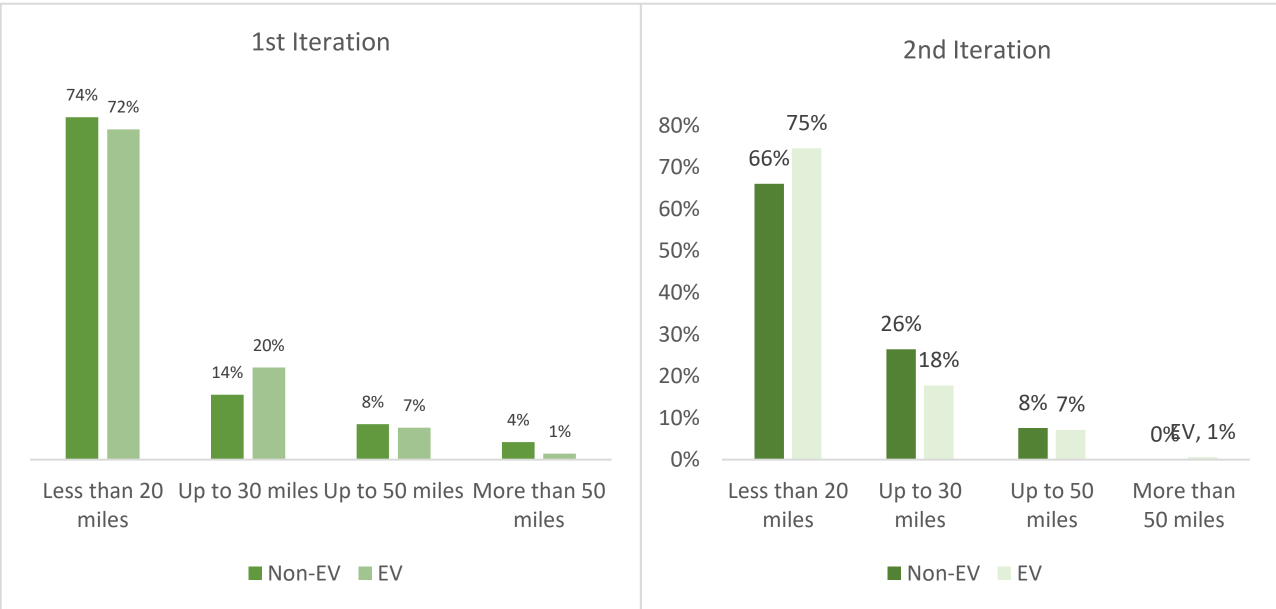
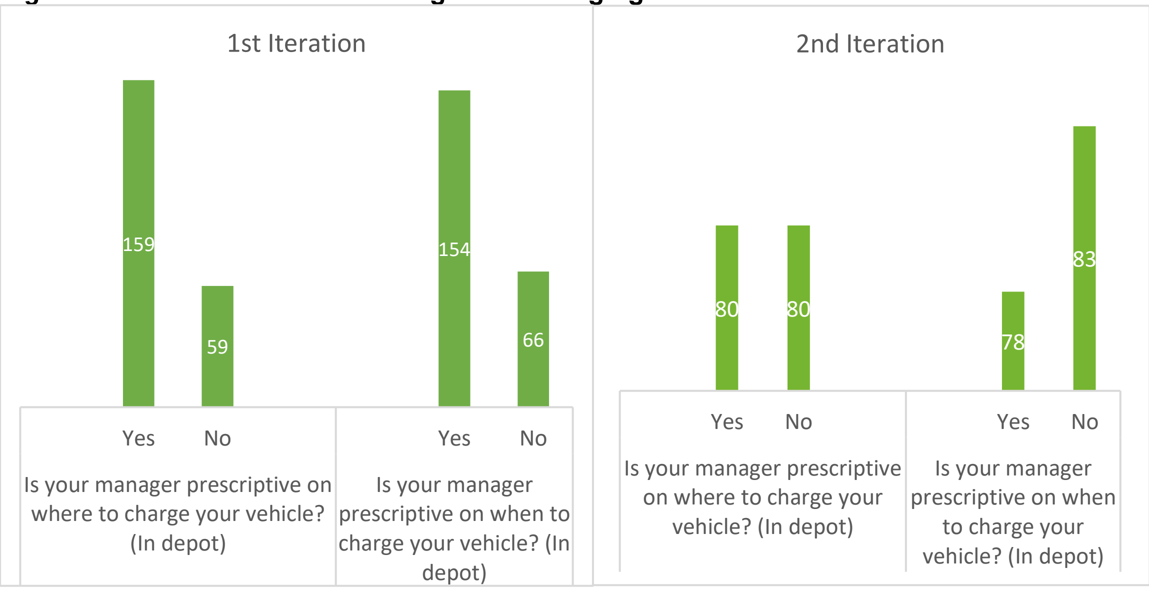


Figure 58 – Maximum distance during given shift



EV charging: the first iteration showed that 73% of EV drivers believe their managers are prescriptive on where to charge and 70% for when to charge (Figure 59). At some depots, the number of vehicles was higher than the number of CPs and drivers were plugging their vans in every other day. Royal Mail's strategy is to move to a 2:1 vehicle to socket ratio, which will require coordination regarding plug-in times and locations. It is expected that depot managers will issue clear instructions to drivers (or provide instructions on the dashboard of each vehicle). In the second iteration of the survey there was no clear tendency towards a yes or no answer to either question – 50% of the drivers responded that their manager is not prescriptive on where to charge and 52% for when to charge (Figure 59). This may also be linked to increasing experience with EVs among the drivers requiring less direction from their managers.

Figure 59 – Drivers' view on management charging instructions

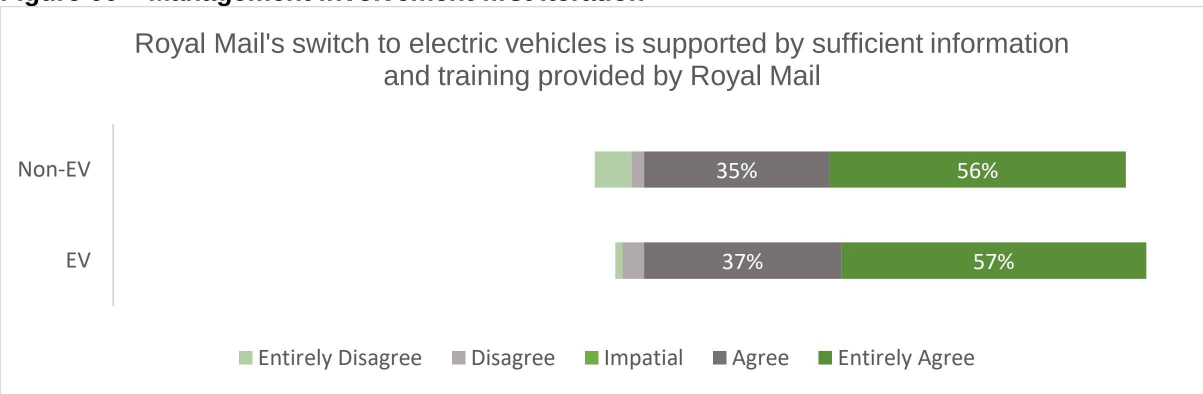


4.2.1.2.2 Opinions on Management Involvement

Royal Mail drivers and depot managers are not involved in decision making regarding vehicle technologies and were not directly consulted on the decision to switch to EVs. The focus was instead on providing information and training, as well as ensuring any impact on their tasks is minimised. Therefore, questions related to drivers' being consulted in the decision-making process were not asked. When comparing these results to other fleets', the equivalent category of 'Considerations of drivers' perspective' included questions on driver consultation and input into decisions on vehicles and related technologies.

Management Involvement was seen very positively by the drivers, with 94%/91% of EV and 91%/95% of non-EV drivers agreeing that support was sufficient, and that Management was making sure that electrification had minimal impact on their daily tasks, respectively (Figure 60).

Figure 60 – Management involvement first iteration



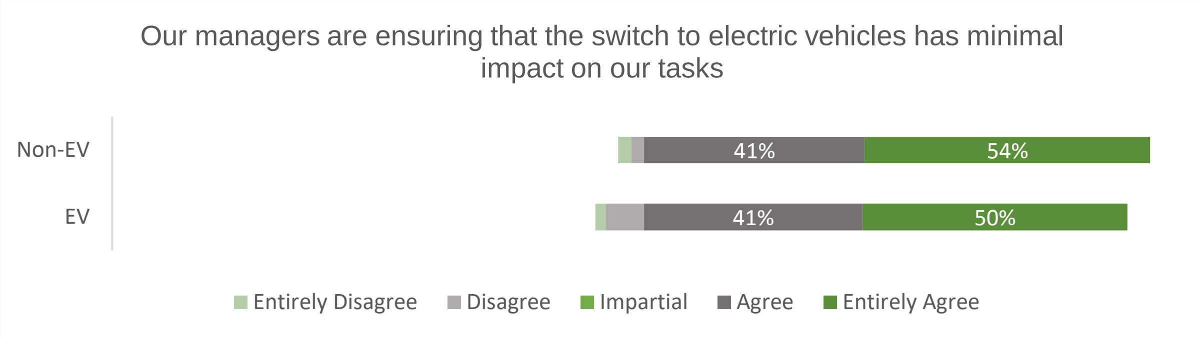
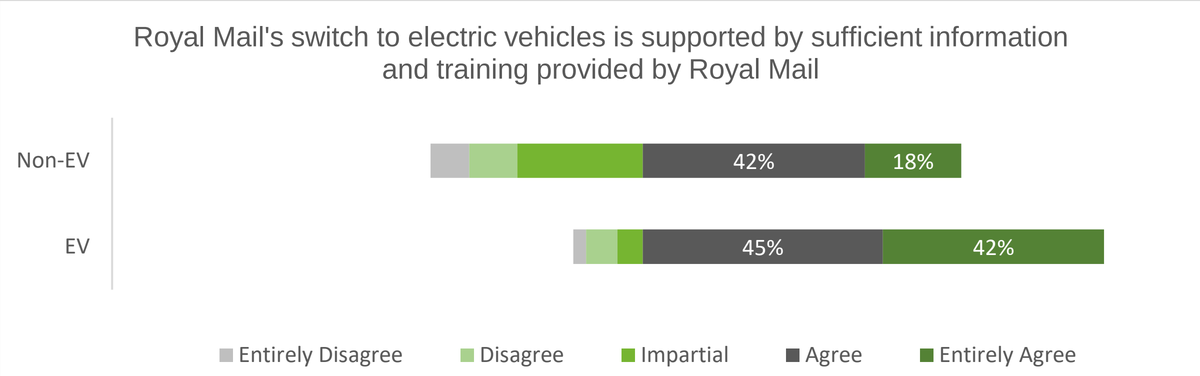
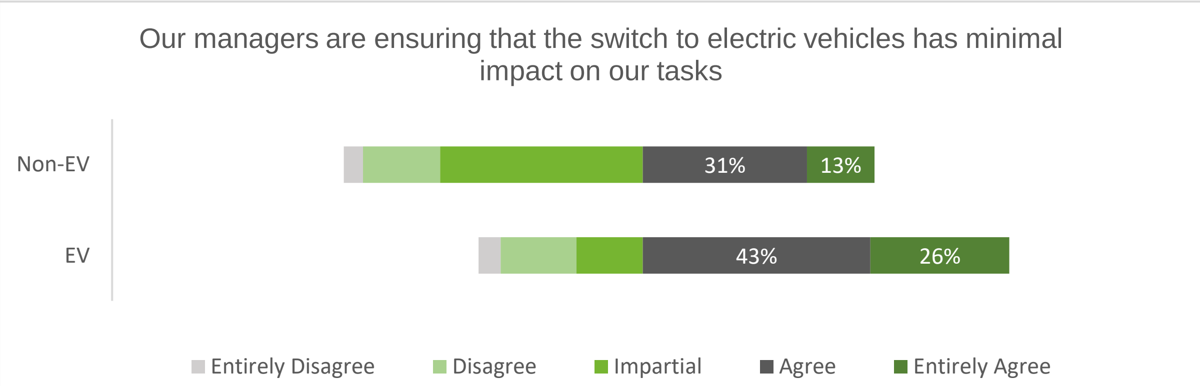


Figure 61 – Management involvement second iteration





4.2.1.2.3 Performance Expectancy

Performance of EVs (acceleration and noise) was regarded very positively by most drivers during first and second iteration of the survey (Figure 62 and Figure 63). However, during the first round of questionnaires, some drivers noted the lack of noise was a problem for pedestrians. The drivers would prefer a reversing sound to make pedestrians aware of the EV. This has now been introduced by Royal Mail. During the second iteration, the positive responses slightly declined. Some drivers reported that although acceleration is very good, it appears to drop significantly once the battery level goes below 50%.

Figure 62 – Performance Expectancy first iteration

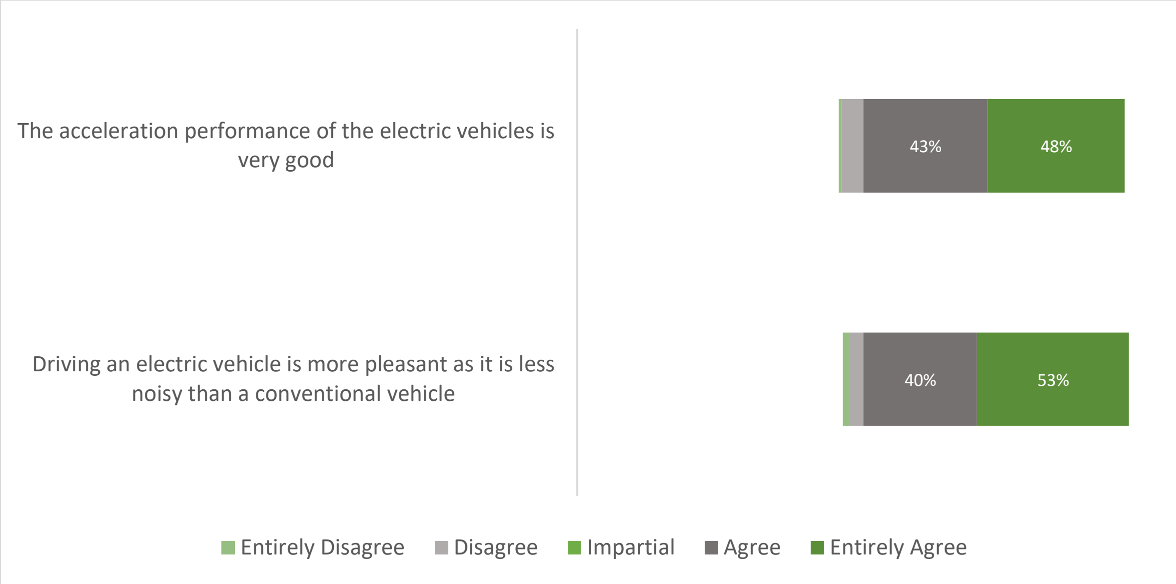
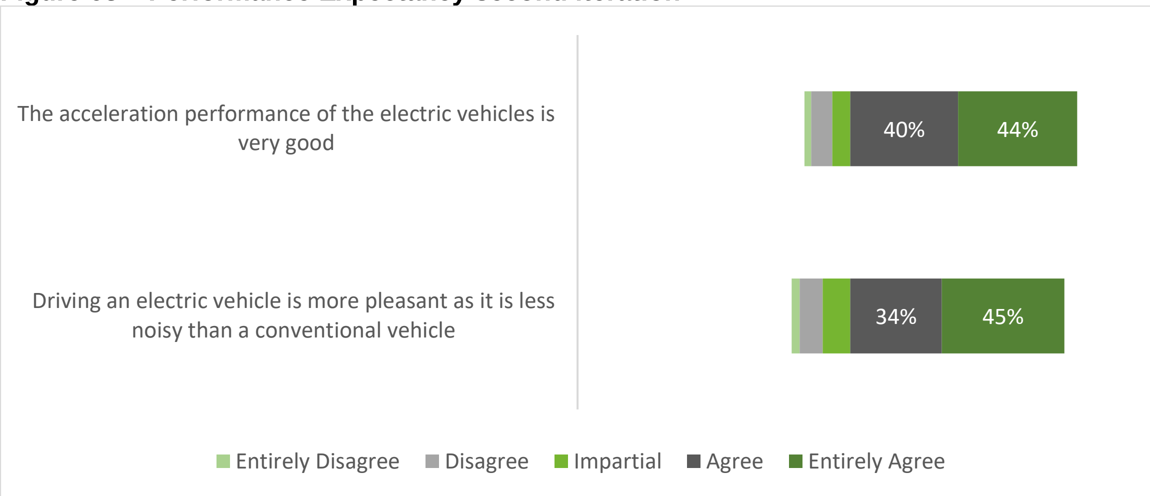


Figure 63 – Performance Expectancy second iteration



4.2.1.2.4 Effort Expectancy

Charging facilities: During the first iteration, the availability of charging facilities was not seen as a problem with only 38% of EV drivers and 12% of non-EV drivers regarding this as an issue (Figure 64). However, 60% of drivers at Bexleyheath agree that limited charging facilities have made their daily work more problematic. During the first iteration, this was the depot with the highest vehicle to CP ratio and limited parking space, requiring the vehicles to be moved around for charging and with most vehicles being charged every other day. In June 2021, many drivers highlighted a concern that the pace of EV vehicles arriving at depot is not being matched by the pace of CP installation. During the second iteration, the problem with limited charging points become even more significant, with the drivers expressed that this is becoming an everyday issue. Some drivers said they are not always able to connect their vehicle for charging because all of the CPs are taken and there is no guarantee that before the next shift their vehicle will be charged. As seen if Figure 65, 72% of EV drivers and 79% of non-EV drivers agree that limited charging facilities makes it more problematic to use an EV versus an ICEV to fulfil daily work tasks.

Figure 64 – Drivers' view on the impact of charging facilities on their daily tasks first iteration

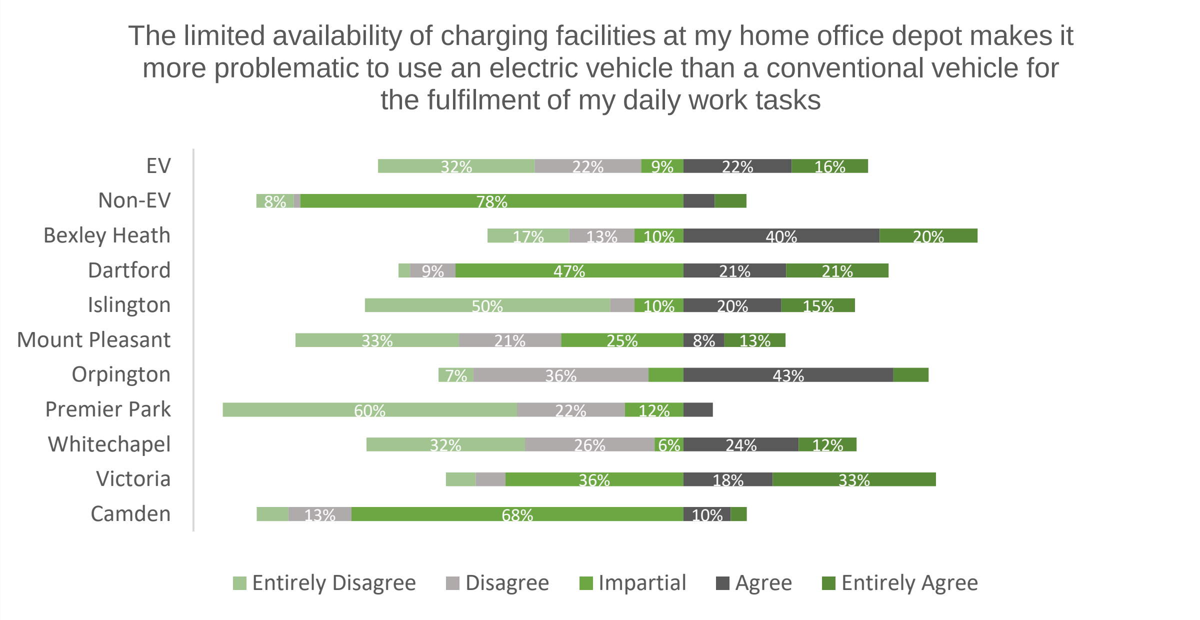
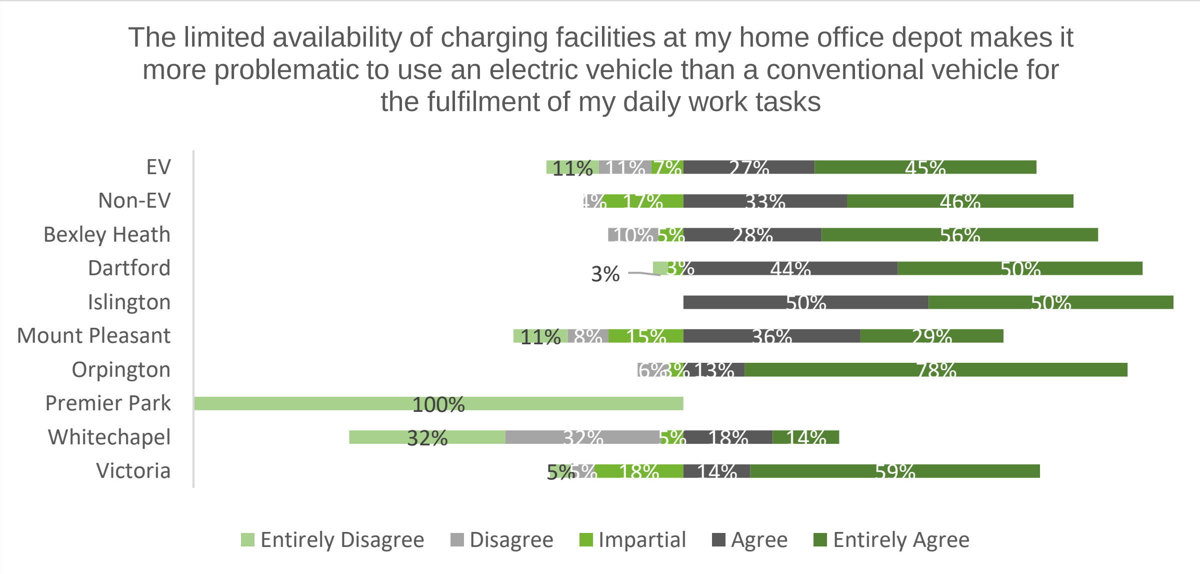


Figure 65 – Drivers' view on the impact of charging facilities on their daily tasks second iteration



Range: During the first iteration, EV drivers were positive about the range of EVs with 74% disagreeing that limited range of EVs makes daily work more difficult, which was expected given the short distances driven (Figure 66). During the second iteration, there were only 53% disagreeing with that statement which might be since the second round of interviews was conducted during wintertime and many drivers reported that when the heating is on, range drops significantly (Figure 67). At Islington, only 58% of the EV Drivers disagreed with the statement that limited range of the EV make it more difficult to fulfil their daily work tasks.

Charging durations: During the first iteration only 28% of EV drivers agreed that long charging durations were impractical, while during the second iteration the percentage of EV drivers agreeing with that statement increased by 12%, even though most vehicles are charged overnight. However, the EV Effort results from the Islington depot, in the first iteration, align with the overall EV Effort second iteration results. 61% of the Islington drivers agreed that long charging durations of the vehicle are very impractical. This might explain why only 52% of Islington depot drivers answered that they prefer an EV to an ICEV (Figure 56, first iteration).

Figure 66 – EV Effort first iteration

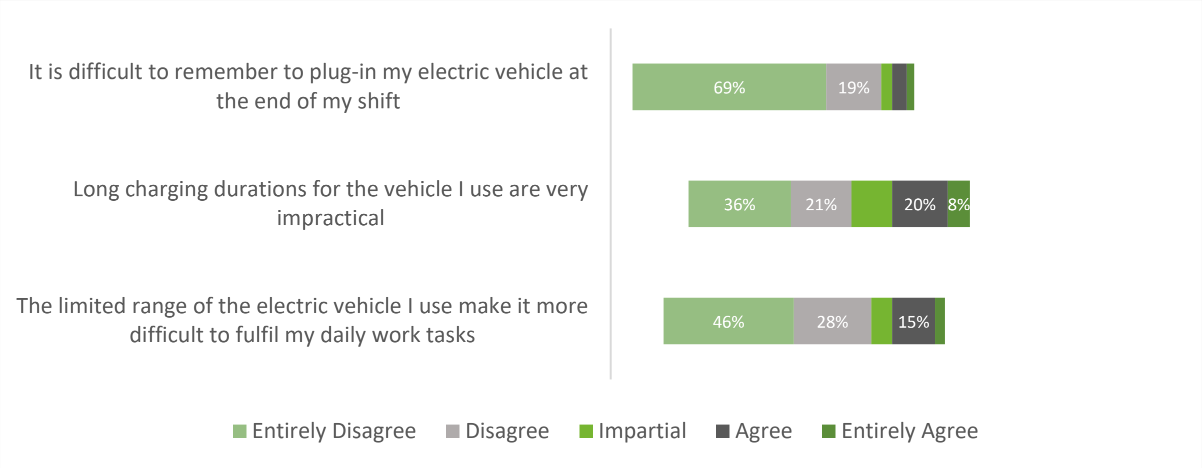
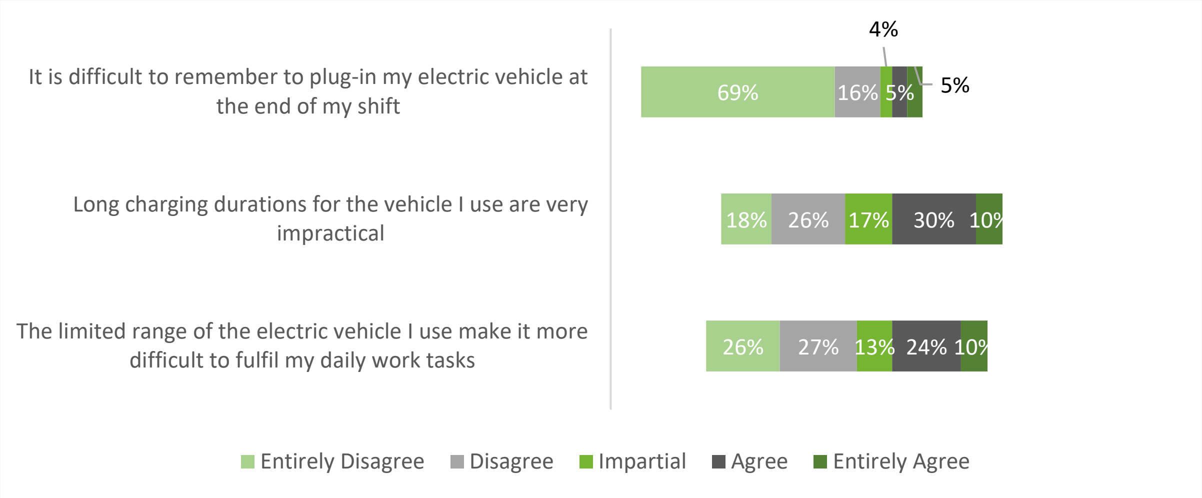


Figure 67 – EV Effort second iteration



4.2.1.2.5 Attitudes, Emotions and Social Influence

Drivers are positive overall about EVs, and the results do not vary significantly between EV drivers and non-EV drivers or between depots. The only significant discrepancy between EV and non-EV drivers can be seen in Question AI4 (I think that electric vehicles are generally cool and pleasant to drive) in both iterations (Figure 68 and Figure 69). More EV Drivers agreed with that statement than non-EV drivers. In the first iteration 86% of EV drivers replied positively compared to 52% of non-EV drivers. In the second iteration, 78% of EV drivers agreed with that statement compared to 48% from non-EV drivers. Also, Question AI2 which states that EVs would be beneficial to the environment in the long term scored the highest agreement number from EV and non-EV drivers across both iterations.

Figure 68 – Mean responses to Attitudes/Emotions & Social Influence questions – first iteration

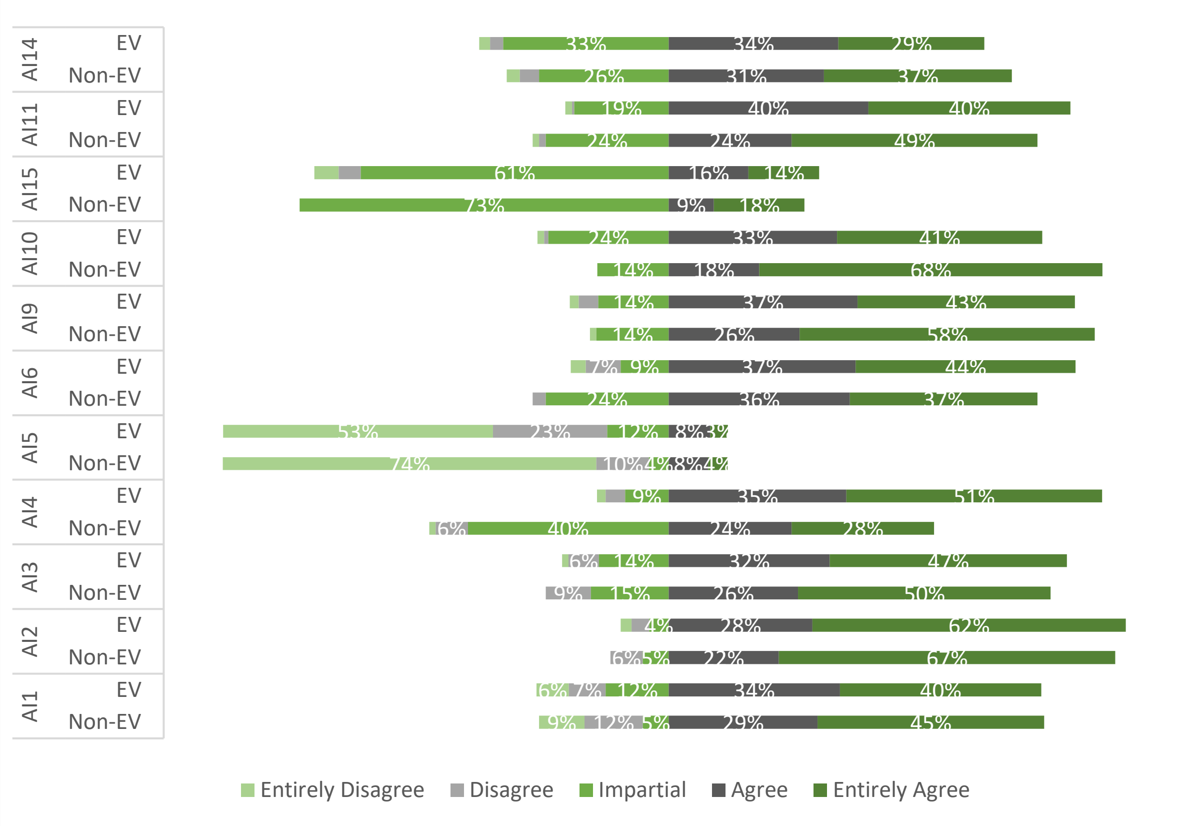
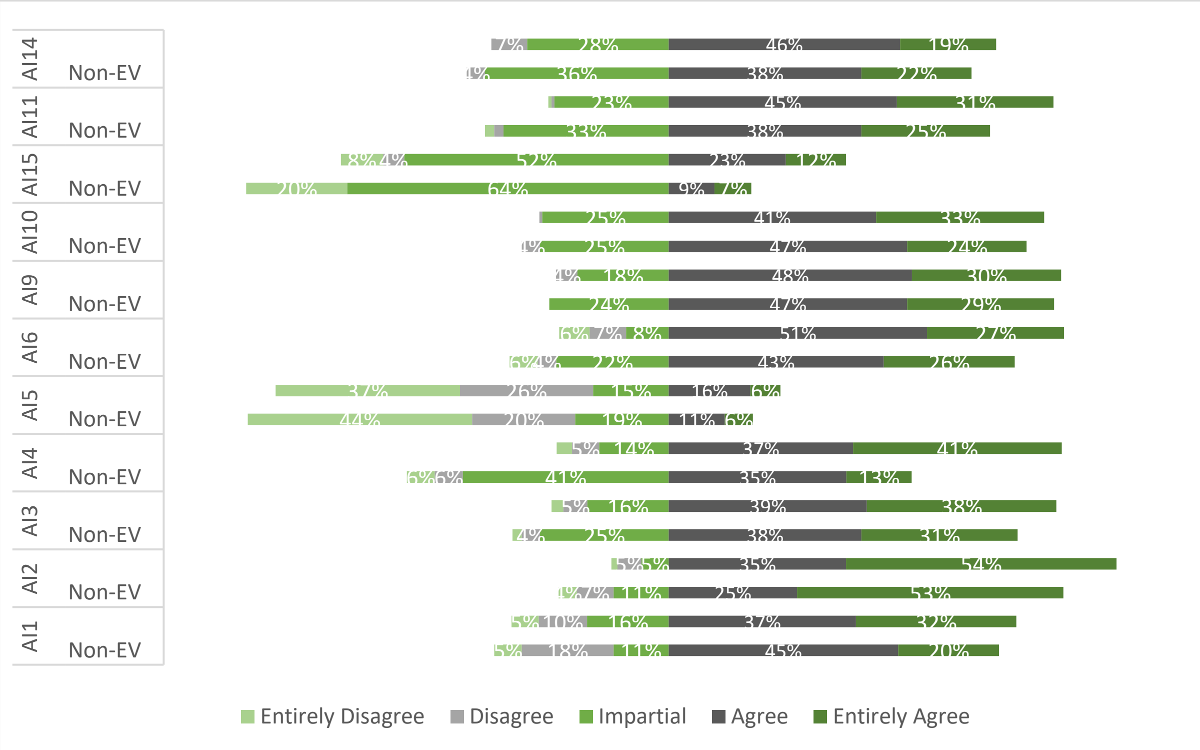


Figure 69 – Mean responses to Attitudes/Emotions & Social Influence questions – second iteration



4.2.1.2.6 Summary of qualitative comments

Figure 70 shows the frequency of keywords in the comments entered by the respondents in the first iteration. The lack of noise resulting in potential for collisions with pedestrians, as well as issues with charging/CPs were mentioned most frequently. Figure 71 shows that the majority of the keywords were charging and charging points which reflects the increase in number of drivers who agree that limited charging facilities impact their daily tasks, as seen in Figure 65.

Figure 70 – Keyword Frequency, first iteration

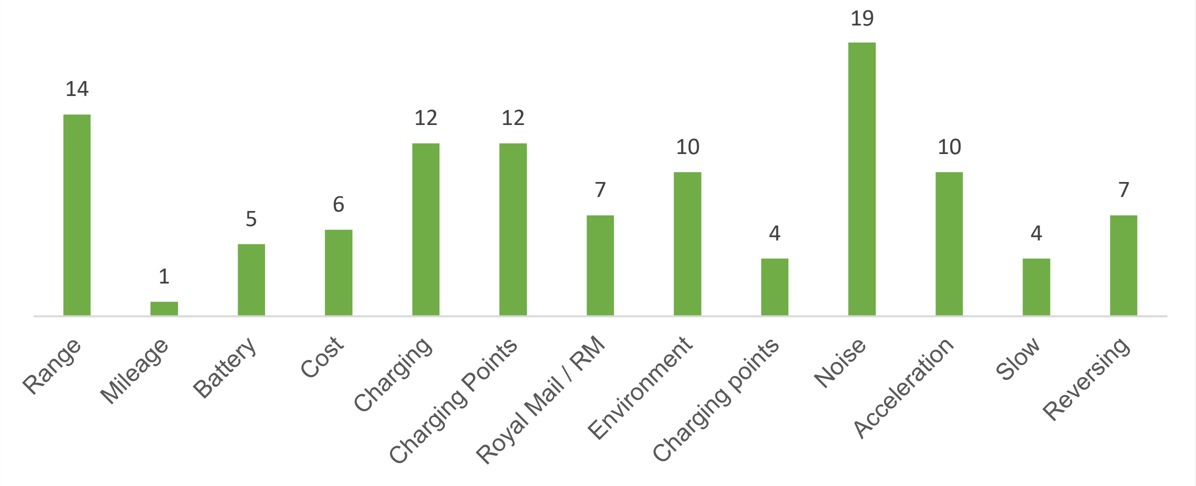
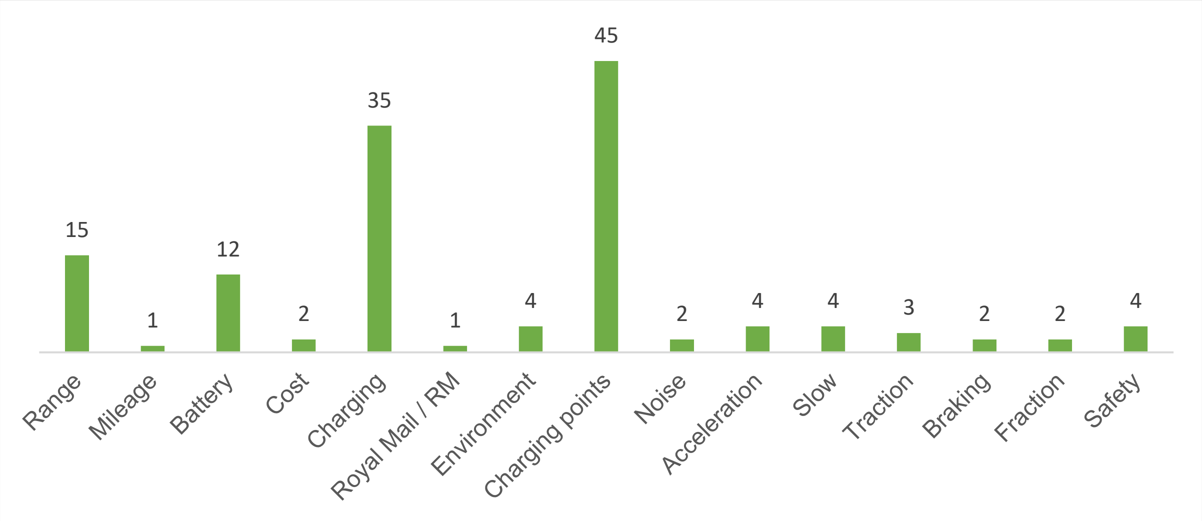


Figure 71 – Keyword frequency, second iteration



4.2.1.3 Depot Managers' questionnaire results

4.2.1.3.1 Overview

The Depot Manager's role is focused on operational responsibilities, such as scheduling, staff management, as well as coordination of vehicle availability. A depot may have a number of Depot Managers (specific job titles may differ), Depot Managers are not responsible for the success of the rollout of EVs or the charging infrastructure within their depots. They also do not have responsibility for the running costs, such as electricity and fuel. 15 depot managers responded to the first questionnaire.

Results from the first Iteration show that only 37% of depot managers had driven the EVs (Figure 72). This number increased to 100% during the second Iteration. However, the number of respondents during second round of questionnaires decreased from 16 to five. (with 80% of respondents to the second iteration had also responded to the first iteration. Regarding decision making about vehicle technologies, fleet management and energy management technologies, 50% of depot managers during first Iteration believe that decisions are highly centralised (Figure 73). This answer was also selected by 80% of the respondents during the second iteration.

Figure 72 – Frequency of depot managers driving EVs

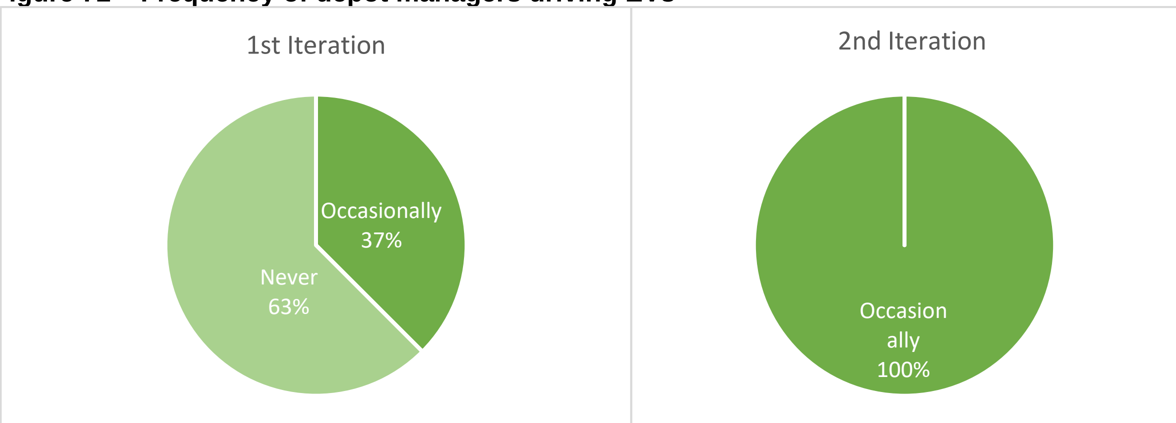
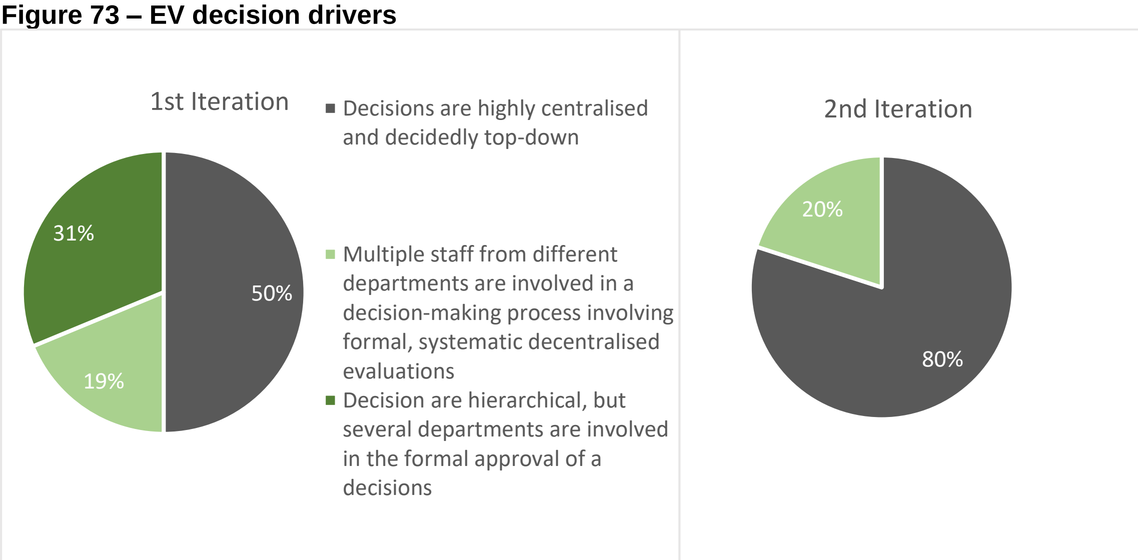


Figure 73 – EV decision drivers

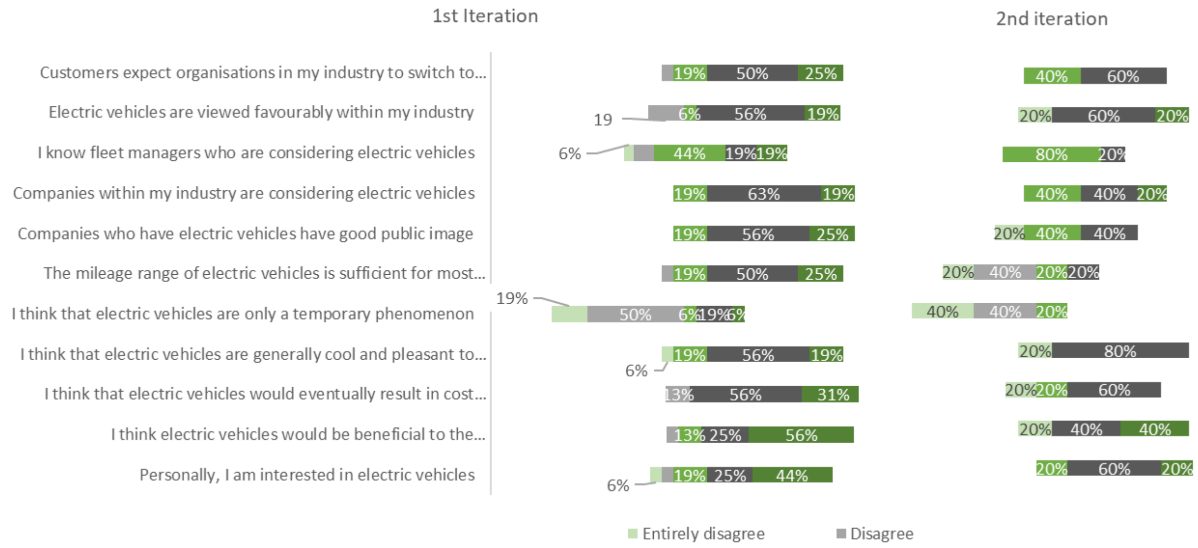


4.2.1.3.2 Attitudes, Emotions and Social Influence

During the first iteration of the questionnaire, 87% of depot management agree that EVs will result in cost savings in the industry, compared to 79% of EV drivers and 76% of non-EV drivers (Figure 74). During the second Iteration, the number of depot managers who agree with that statement decreased to 60%, while the drivers remained at a higher level with 77% agreement from EV Drivers and 69% from non-EV Drivers.

A significant change can be seen in the response to the statement that ‘mileage range of EVs is sufficient for most shifts’. While the percentage of the drivers agreeing with this statement remained high between both iterations, 75% of the depot managers agreed with that statement in iteration one, declining to 20% in iteration two. This could be linked to higher battery usage during wintertime, although no comments were received to substantiate this.

Figure 74 – Mean manager responses to Attitudes/emotions and social influence questions



4.2.1.3.3 Summary of qualitative comments

One issue repeated in comments across both iterations was regarding breakdown recovery and servicing. In both instances, the problems identified were due to the length of time it takes to service EVs, slow recovery of a breakdown and limited support provided during a breakdown.

4.2.1.4 Corporate Management

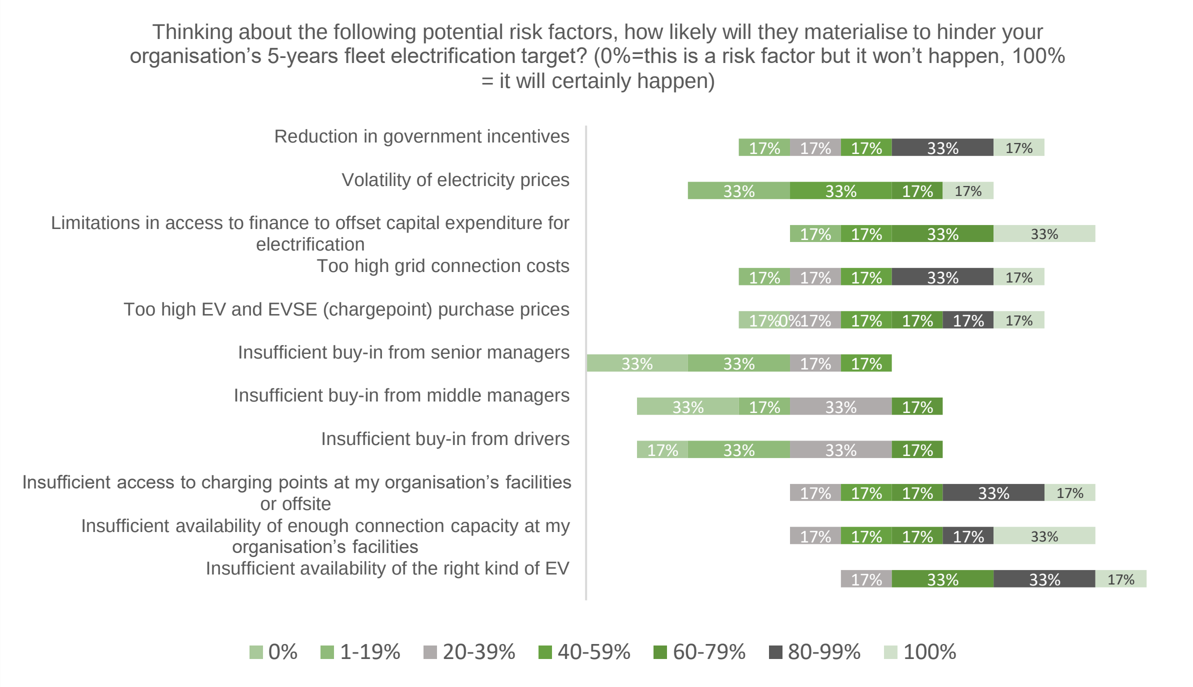
4.2.1.4.1 Overview

All survey participants were aware of EVs and smart charging being used or planned to be used. Five out of six were aware that data monitoring and software technologies to optimise energy/fuel use were in use or planned to be used. However, only one member of management was aware of an organisation-wide target for EV penetration over the next five years, which they said to be ‘Up to 30%’.

4.2.1.4.2 Risk to EV adoption

A lack of ‘buy-in’ from staff at different organisational levels (senior management, middle management or drivers) is seen as least likely to hider the transition to EV, while insufficient availability of the right type of EVs is seen the biggest risk was seen as the biggest risk (Figure 75).

Figure 75 – EV risk factors



4.2.1.4.3 Barriers to EVs

Participants were asked to list the three most important external barriers to the full electrification of their fleet. Availability/supply of the right type of vehicles is seen as the main barrier by all respondents. There is also an awareness of the electricity network capacity issues, with five out of the six respondents referring to this.

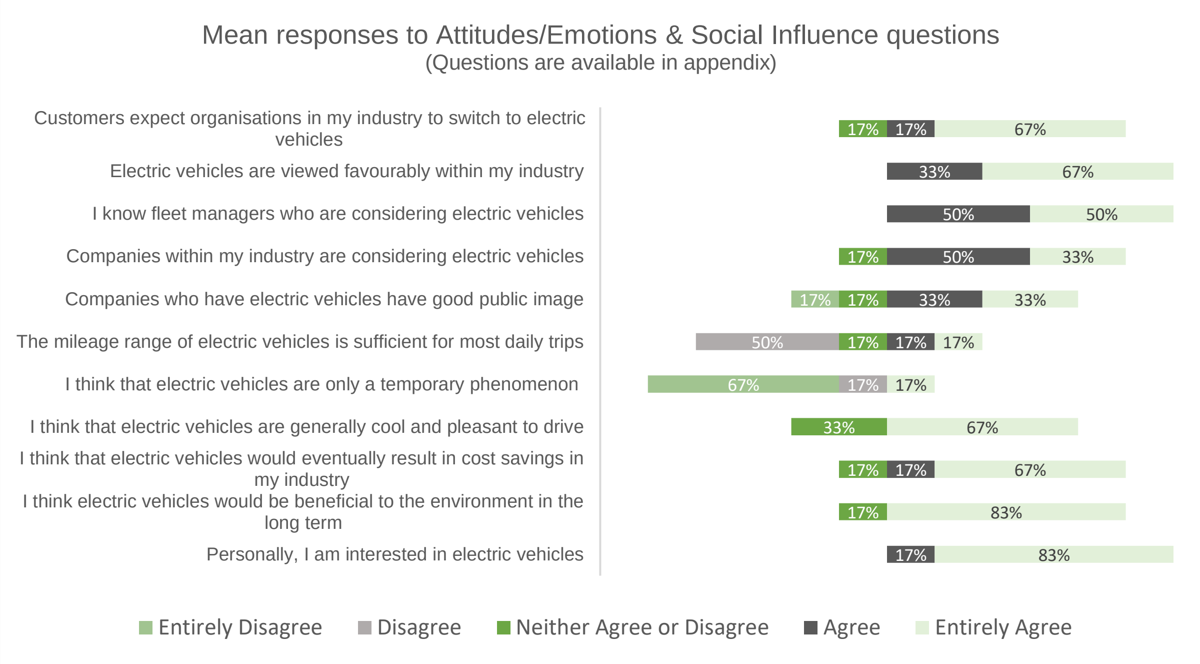
4.2.1.4.4 Enablers to EVs

Participants were also asked to list the three most important external enablers to the full electrification of their fleet. The responses were mostly around government action (legislation or incentives), cost effectiveness and ability to reduce the environmental impact of the company.

4.2.1.4.5 Attitudes, Emotions and Social Influence

Overall, Corporate Managers have a positive view of EVs and have all expressed personal interest in them. However, they do show concerns around the range of the EVs, with only 34% agreeing that it is sufficient for most daily trips (Figure 76). This question did not focus on the use of EV for Royal Mail purposes, so it is likely that this is a broad concern, rather than specific to the range requirements of Royal Mail's corporate fleet.

Figure 76 – Management Attitudes/Emotions and Social Influence responses



4.2.1.5 Summary of key learnings

Royal Mail drivers prefer EVs to ICEVs

Although the level of agreement varied from depot to depot, both iterations showed that overall, drivers prefer to EVs to ICEVs with the majority of EV drivers responded positively to statements regarding driving experience.

View on EV Effort changes with more EV experience

Six months after the first iteration, fewer drivers disagreed with the statement 'the limited range of EVs make it more difficult to fulfil daily work tasks'. This also aligned with the view from depot managers as in their second iteration, number of depot managers who agreed that milage is sufficient for most shifts declined to 20%. Additionally, more drivers in the second iteration agreed that long charging durations are very impractical.

Charging facilities play a key role in drivers' perception of ability to fulfil their daily work tasks

During the second iteration of the drivers' questionnaire the number of EVs across depots cumulatively increased by 26% while the number of charging points remained the same. This probably had impact on the responses in second round of the survey where the number of drivers who agreed that limited availability of charging points make it more problematic to fulfil their daily work tasks increased from 31% (both EV and non-EV) to 73%.

EVs are seen as beneficial to the environment in a long term

Agreement with the statement was voiced by EV drivers, non-EV drivers and depot management alike. Ability to reduce environmental impact of the company was also mentioned as one of the biggest enablers of EV adoption by corporate management respondents.

EVs are seen to result in cost saving in the industry

This statement received a high percentage of agreement across both iterations both from drivers and depot management.

Risks, barriers and enablers of EV adoption were identified through the survey of corporate management:

- Insufficient availability of the right kind of EVs seen as the biggest risk and barrier to EV adoption
- Government actions (legislations or incentives) seen as one of the main enablers to EV adoption

4.2.2 Centrica

4.2.2.1 Overview of the Surveys

The Centrica surveys were targeted at British Gas drivers and managers responsible for fleet operations. There were 108 responses to the first survey which remained open for 24 days having been distributed amongst Centrica's British Gas engineers internal Yammer message-board on the 23 February 2021. The second survey remained open for 25 days from the 1 October 2021 and was distributed in the same way, although it yielded 230 responses (Table 37).

Table 37 – Descriptive Statistics of the Centrica British Gas Behavioural Surveys.

	First Iteration	Second Iteration
Distribution Period:	23/2/2021 → 18/3/21	1/10/21 → 25/10/21
Distribution Method:	Centrica via internal Yammer message-board	Centrica via internal Yammer message-board
Total Responses:	108	230
EV Responses:	19 (22% total EV fleet)	86 (12% total EV fleet)
ICEV Responses:	89 (82% of total responses)	144 (62% of total responses)
Demographic:	97% Male Median Age of 35-44	97% Male Median Age of 35-44
Returning Respondents:	Overall, 30 repeat responses were received in the second iteration from those that responded to the first iteration.	

Despite the count of EV respondents being far higher in the second iteration, this represented a relative decrease in the proportion of the EV fleet compared with the first iteration. The 19 drivers who responded to the first survey constituted 22% of Centrica's total EV fleet at that time, whereas the 89 who responded to the second survey represented 12%. Centrica's EV fleet roll-out had progressed over the period that these two surveys were conducted, and so there was a larger pool of engineers driving EVs when the second iteration occurred.

There were 30 repeat respondents who answered both the first and second iterations of the survey. 13 of these drivers responded to the first iteration, as ICEV drivers, but answered the second survey as an EV driver. This gave insights into how opinions about EVs can shift once a driver has experience driving one.

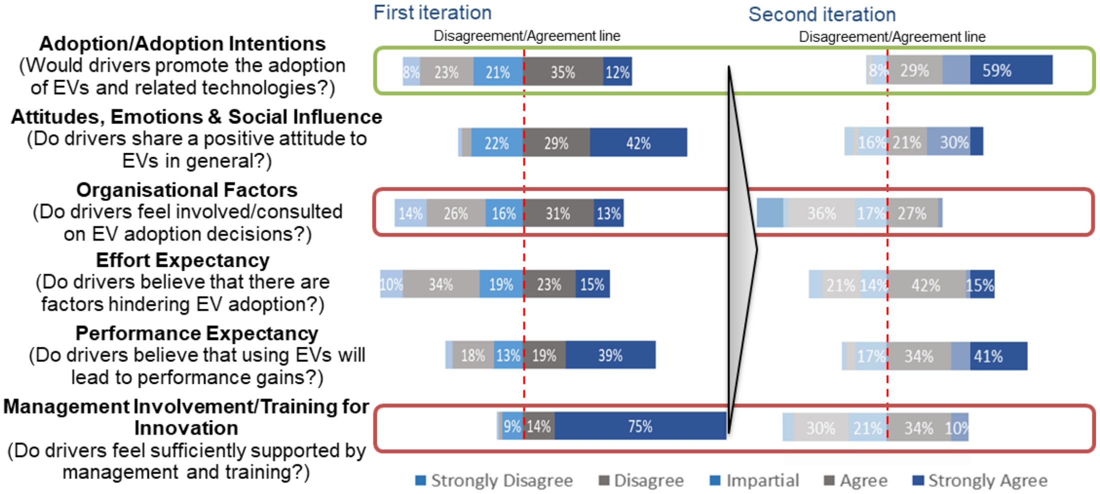
4.2.2.2 General Results

Following the FAST framework methodology, outlined in section 4.1, there were some immediately observable changes to the six fundamental variables measured across the first and second surveys:

- Adoption Intentions
- Attitudes, Emotions & Social Influence
- Organisational Factors
- Effort Expectancy
- Performance Expectancy
- Management Involvement/Training for Innovation.

There was a positive change in measurements of ‘Adoption Intentions’. However there were obvious negative shifts in perceptions of ‘Organisational Factors’ and ‘Management Involvement/Training for Innovation’ (see Figure 77). When examining these results, it is important to note the real-world context in which they were answered. The timing of distribution may have had implications on how positively or negatively the engineers would respond to matters concerning their beliefs about their organisation at that time. The statistical significance of these changes is discussed later in the report. Nevertheless, there is a clear improvement in the extent to which British Gas drivers would promote the adoption of EVs and related technologies in their organisation.

Figure 77 – Overview of the aggregated results according to the FAST framework for both the first and second iterations of Centrica’s behavioural surveys



For presentation purposes, 7-point scale was aggregated to 5-point. Neutral responses showed on a disagreement side

There were further changes between the first and second iterations (see Figure 78). The results of the first survey showed EV drivers reporting lower mileages than ICEV drivers, estimating their typical distance at 50 miles per day and 90 per day respectively. It was perhaps unexpected that EV drivers would report driving further than ICEV drivers in the second survey for both the average typical distances they covered, as well as their maximum distances covered per day.

35 EV drivers (40%) reported driving further than the average typical daily mileage of their ICEV driving counterparts. 34 of these 35 reported that they plugged in their vehicle to charge at home, and only 1 disagreed that free parking would make it easier to use EVs. Although it is un-reliable to make any absolute conclusions from this, these results do suggest there may

be a relationship between a driver's ability to charge their vehicle at home and their confidence or ability to drive long distances while fulfilling their daily tasks.

Figure 78 – Self-reported daily mileages driven by British Gas drivers for both the first and second iterations

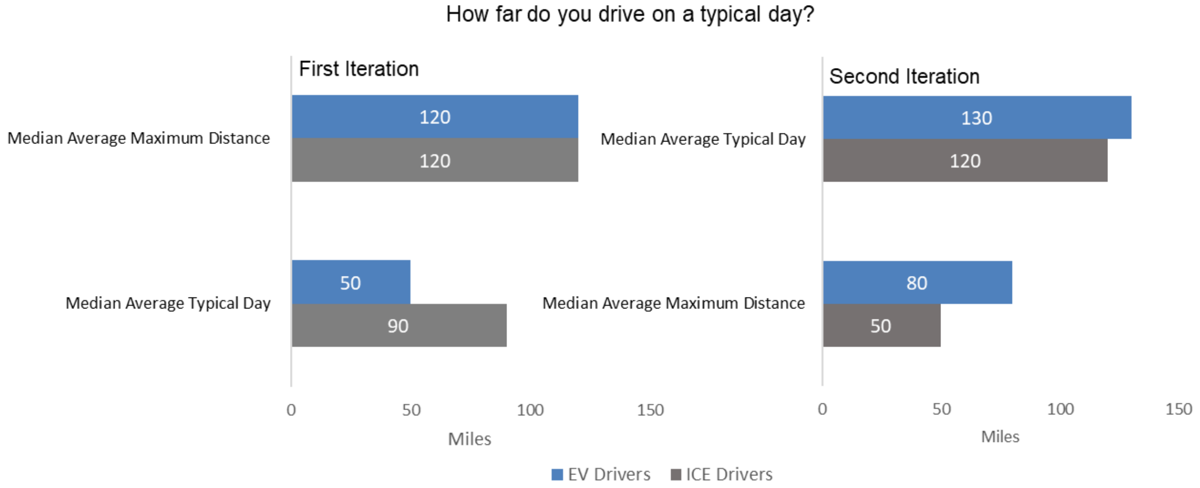
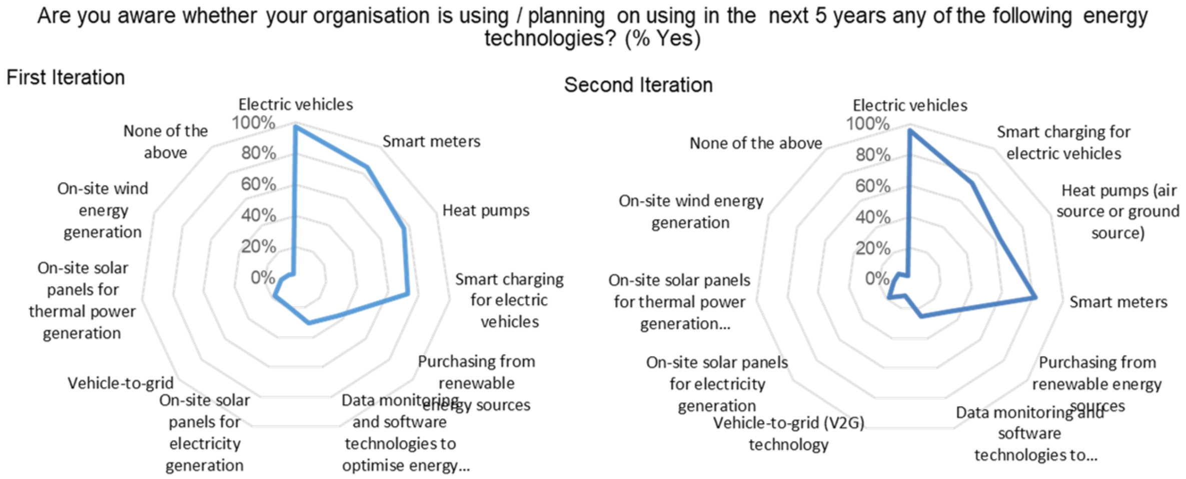


Figure 79 – Awareness of technologies amongst British Gas drivers, from both the first and second iteration



The reported awareness of well-known low-carbon technologies amongst the drivers remained relatively consistent across the two surveys, as illustrated by Figure 79. In both instances, reported awareness was high for EV roll-out in Centrica's fleet, as well as for smart meters and the implementation of smart charging.

Answers on typical charging behaviour cannot be tracked from the first to the second iteration since the wording of the question was changed. The results for both iterations are in Figure 80 and Figure 81.

Figure 80 – Responses on charging behaviour from the first iteration

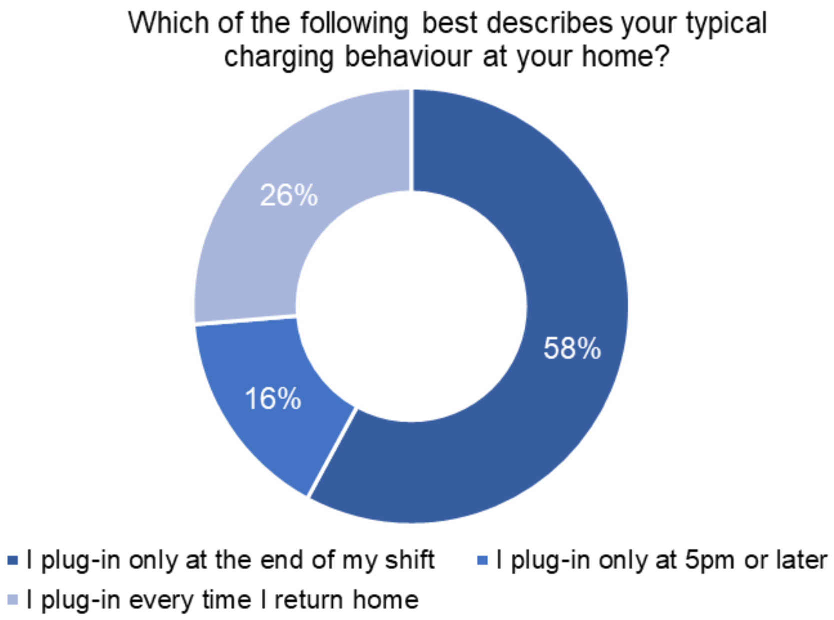
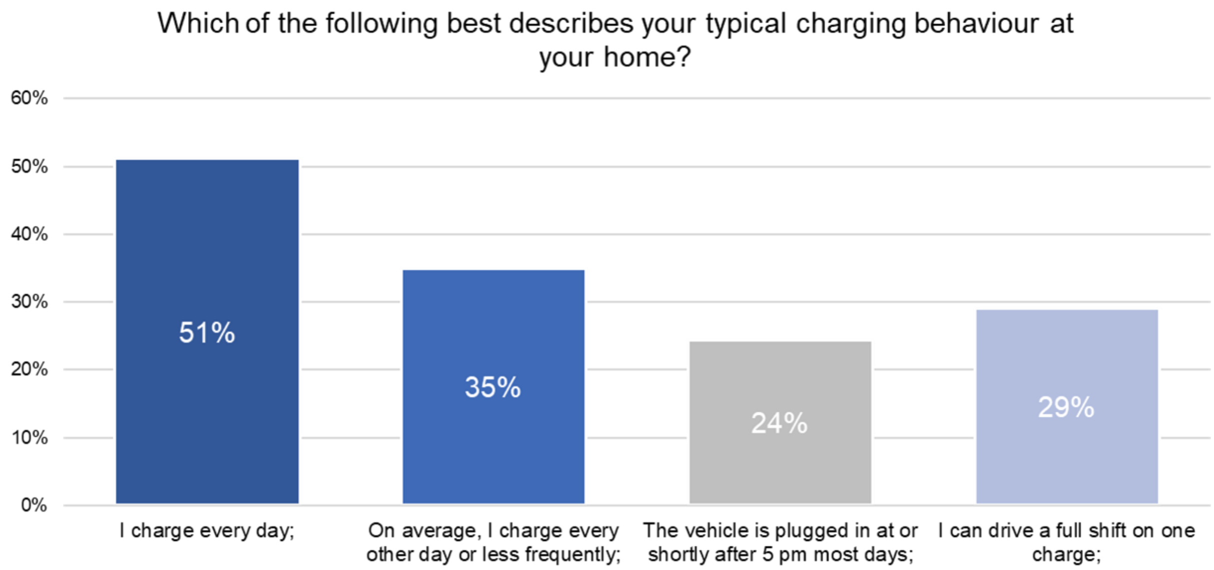


Figure 81 – Responses on charging behaviour from the second iteration

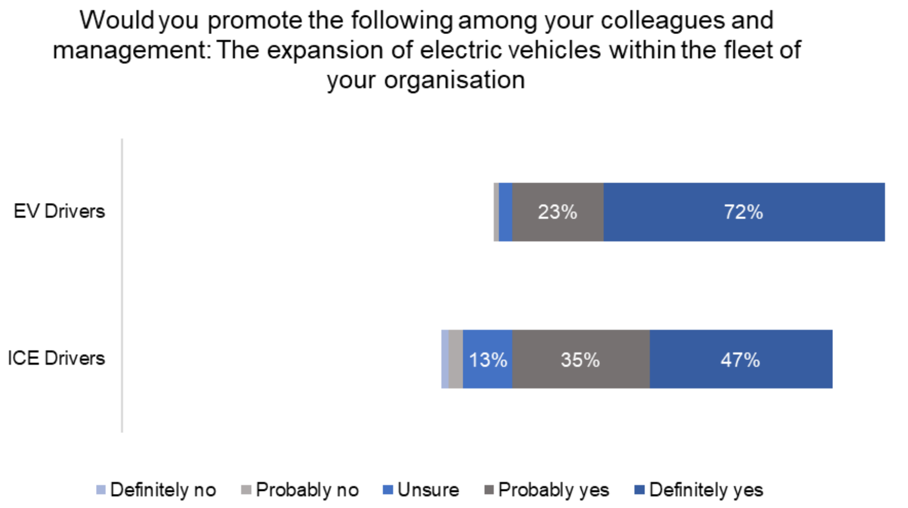


4.2.2.3 FAST Framework Analysis

4.2.2.3.1 Adoption Intentions

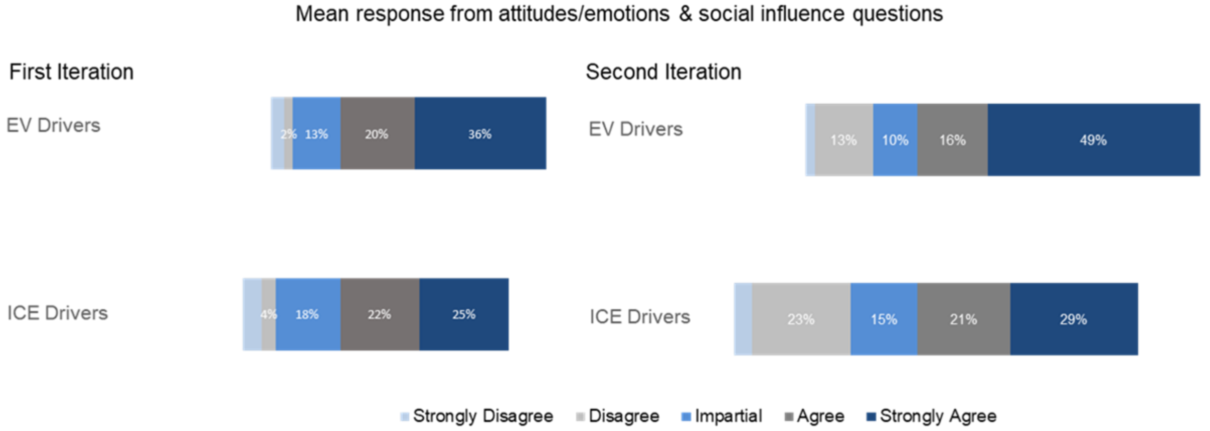
The levels of advocacy British Gas drivers had for adopting EVs remained steadily positive from the first to the second iteration. The results from both surveys showed that 82% of ICEV drivers would promote the transition to EVs. There was a 1% increase in the proportion of EV drivers who would do the same, with 95% in the second iteration compared with 94% in the first iteration (Figure 82). This suggests that there is significant and stable support within Centrica for introducing an electric fleet.

Figure 82 – Adoption Intentions results from the second iteration



4.2.2.3.2 Attitudes, Emotions and Social Influence

Figure 83 – Mean results for Attitudes, Emotions and Social Influence responses for both the first and second iterations

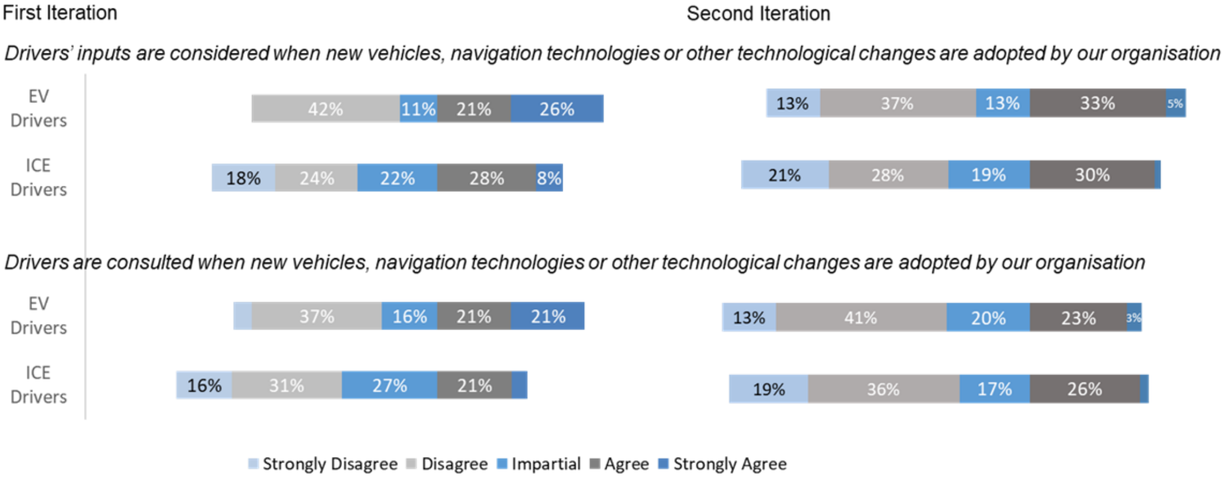


The surveys measured similar levels of attitudes, emotions and degrees of social influence on EVs amongst the British Gas driver sample (Figure 83). In both iterations, over half of EV drivers exhibited positive attitudes towards EVs and EV adoption in the industry. Across both iterations again, there were higher rates of agreement among EV drivers compared to ICEV drivers.

4.2.2.3.3 Organisational Factors

EV drivers feel less connected to technology adoption decisions than they did in the previous survey. 38% (down from 47%) drivers said their inputs are considered, and 26% (down from 41%) feel consulted about the adoption of new technology (Figure 84).

Figure 84 – Responses on Organisational Factors from both the first and second iterations

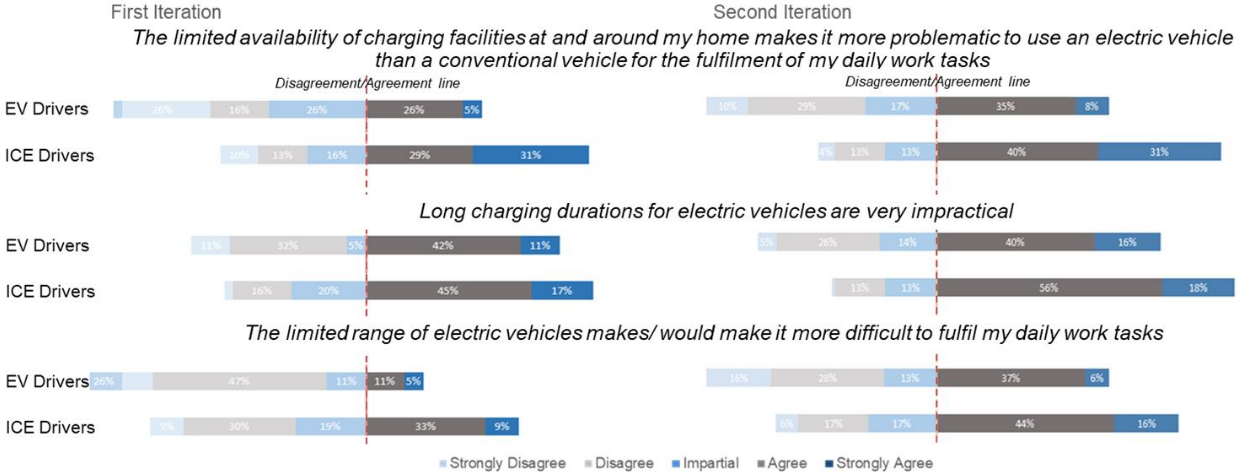


4.2.2.3.4 Effort Expectancy

The Range of an EV has become a common concern amongst EV drivers since the last survey (Figure 85), with 43% now agreeing that the limited range of EVs makes their work more difficult (up from 16%). This could be explained by the increase of the EV fleet roll-out since the first iteration. It is possible that the engineers whose routes were most suited to EVs – those with short daily distances – and those who held more favourable attitudes towards EVs, would be prioritised first in the roll-out and therefore perhaps had positive perceptions on EV range. However, as more and more EVs are rolled-out, the dominance of this early-adopter group would reduce as more engineers (who drive longer distances and perhaps hold less enthusiasm) start driving EVs.

Corroborating this, Figure 78, showed EV drivers were driving further in the second iteration. As a result, they would be draining more energy from their battery on-shift perhaps contributing to greater range anxiety. These drivers would also be more likely to be charging at public charging stations which, for new EV drivers, would be a new and potentially less desirable experience being more time-consuming than refuelling ICEVs.

Figure 85 – Results for Effort Expectancy for both the first and second iterations

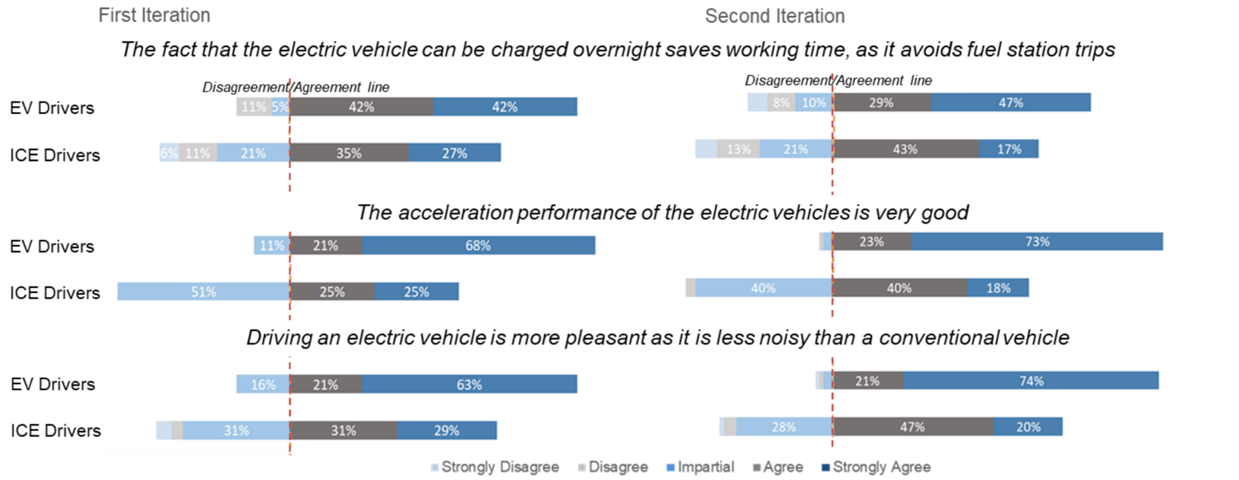


4.2.2.3.5 Performance Expectancy

Perceptions of EV performance – in terms of acceleration and more pleasant driving experience – have become more positive since the first survey amongst both EV and ICEV drivers (Figure 86). The second survey showed EV drivers to be overwhelmingly positive about the acceleration and the quietness of the vehicles with 95% having positive feelings for both points.

There was a slight decrease in positivity when the drivers were questioned on the fact EVs could save working time by being charged overnight, from 84% showing positivity in the first to 76% in the second surveys. As described in Section 4.2.1.2.4, on 'Effort Expectancy', this may also indicate the slight dip in enthusiasm for EVs as the positive early adopters begin to constitute a smaller percentage of the overall fleet.

Figure 86 – Results for Performance Expectancy for both the first and second iterations



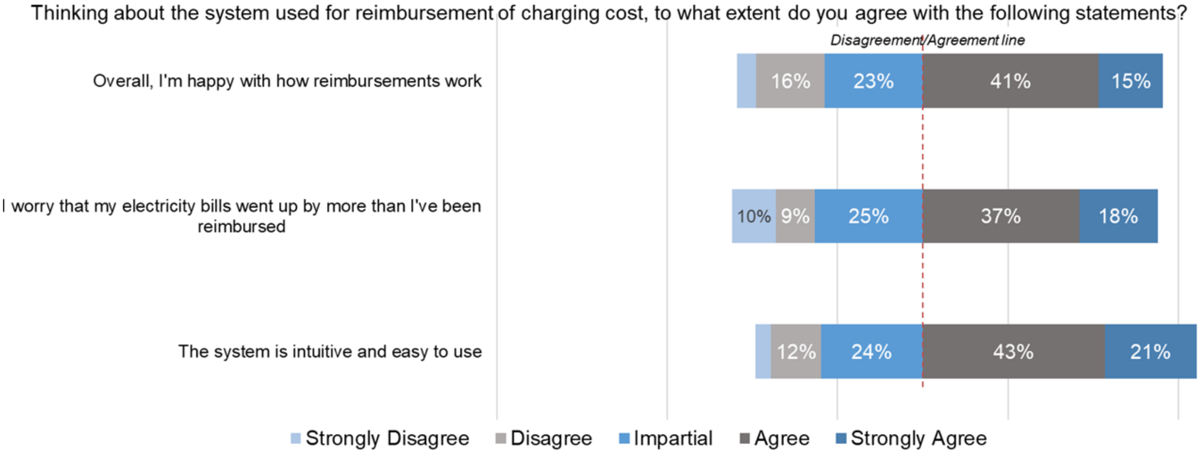
4.2.2.4 New Questions in the second iteration

4.2.2.4.1 Reimbursements

As is the case for diesel payments, Centrica's engineers get reimbursed for all the electricity they use for their vehicles although the process is different. Since a large proportion of charging occurs at engineers' homes, Centrica has established a reimbursement system where a driver submits their bill and the energy drawn from the vehicle is automatically calculated. The associated cost is then reimbursed directly to the engineer at the end of each month.

There were positive perceptions of this reimbursement system as illustrated by Figure 87, however overall this topic revealed balanced views. Further discussion of Centrica's system for energy cost reimbursement can be found in section 6.1.2.

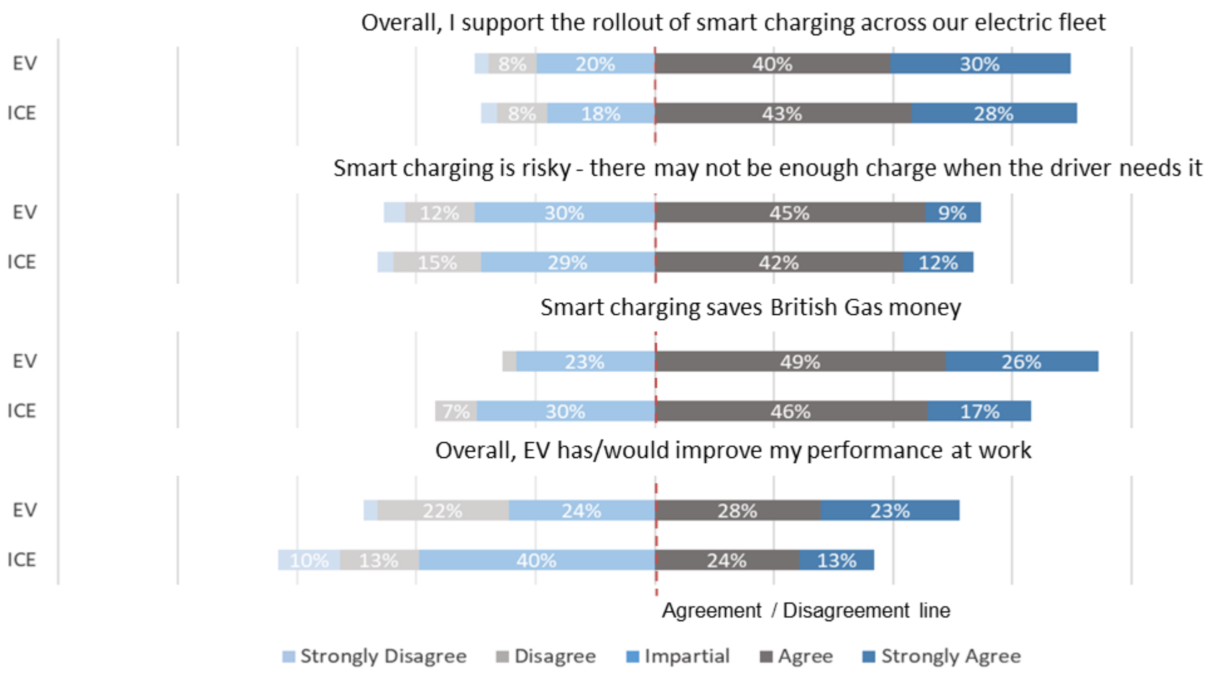
Figure 87 – Perceptions of Centrica's reimbursement system (second iteration)



4.2.2.4.2 Smart Charging

There is a mixed perception amongst British Gas drivers for smart charging (Figure 88). While there was overall support for smart charging, and a commonly held belief it can save the business money, there was also a significant degree of perceived risk that it might not guarantee enough charge. This may be useful in demonstrating that confidence in smart charging is fragile and requires constant communication in order to maintain drivers' confidence in it. This may be the case with all the technologies associated with EV adoption, and decarbonisation more widely.

Figure 88 – Perceptions of Smart Charging (second Iteration)



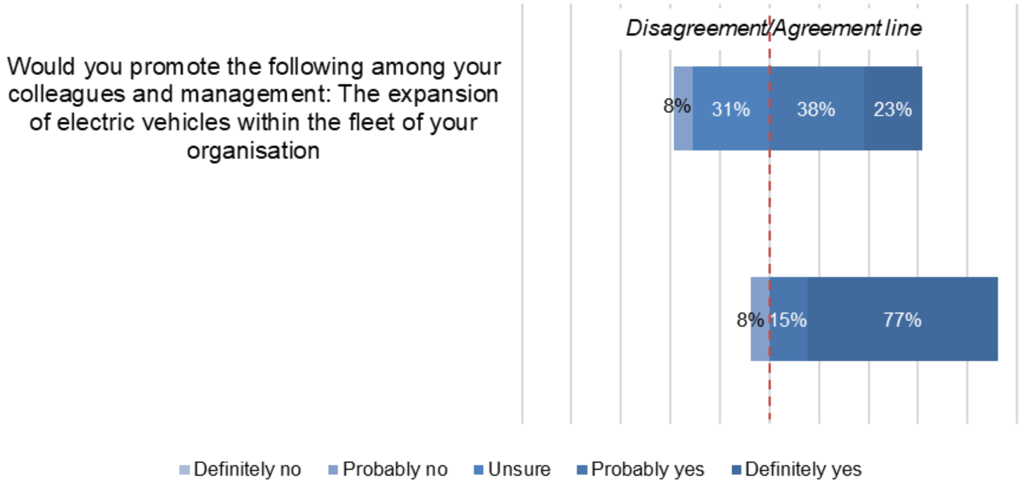
4.2.2.5 The 13 Repeat Respondents: 13 ICEV-EV Transitioned Drivers

There were 13 drivers who responded to the first survey as an ICEV driver, but responded again to the second as an EV driver. This provided an opportunity to measure these drivers' changes in perception of EVs having started to drive one.

4.2.2.5.1 Adoption Intentions

There was a major shift in the extent to which these drivers would advocate for expansion of EVs across the fleet. 92% of these 13 transitioned drivers said they would promote EVs in their organisation in the second survey, whereas only 61% would when they responded to the first survey as ICEV drivers (Figure 89).

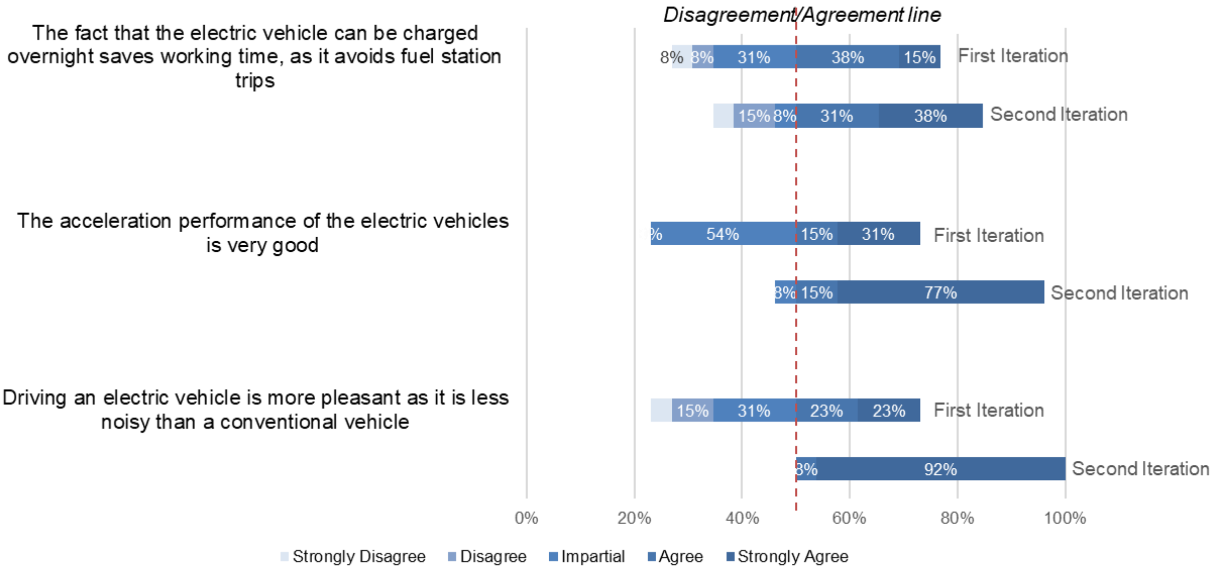
Figure 89 – Adoption intentions of the 13 transitioned drivers



4.2.2.5.2 Performance Expectancy

There were significant improvements on expectations of performance of EVs throughout this group. Every driver believed driving an EV to be more pleasant than an ICEV, when previously less than half of the drivers had this attitude (Figure 90). A similar improvement was measured for beliefs on the performance of EVs where 92% (up from 46%) believed the vehicle's performance to be very good. There was also an improvement on the increased practicality of EVs since they can save working time by charging at home while engineers are off-shift. These results are positive in demonstrating the value of EVs, not only for the environment, but also for the drivers' experiences.

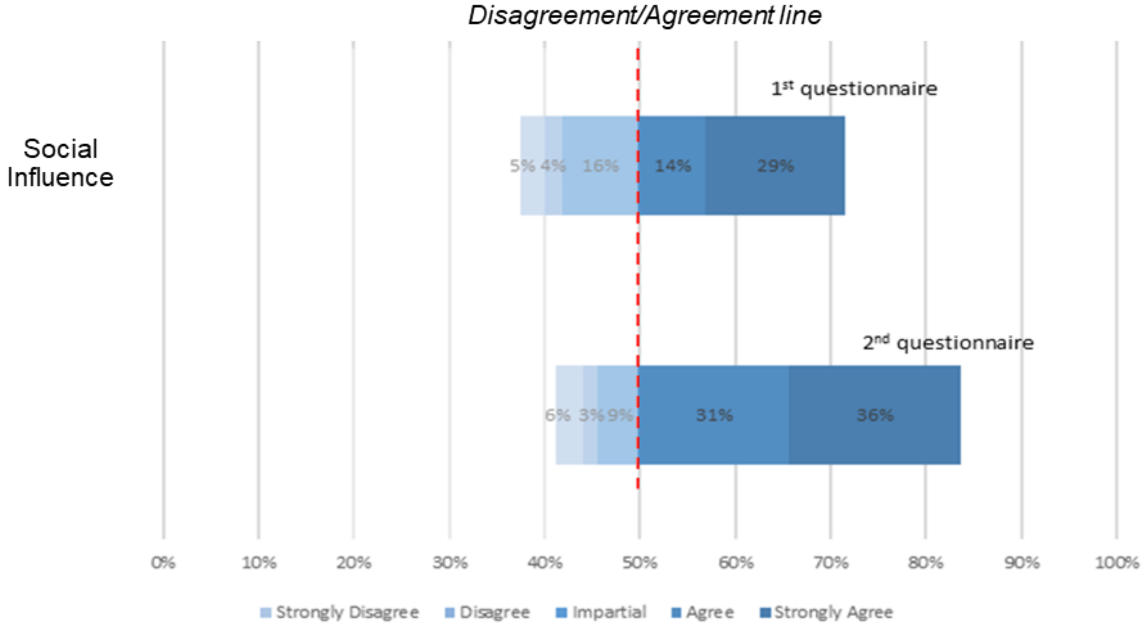
Figure 90 – Performance Expectancy of the 13 transitioned drivers



4.2.2.5.3 Social Influence

Having driven an EV, this sub-sample responded more favourably in the metrics measuring ‘Social Influence’ around EVs than they did in the first survey (Figure 91). This was derived from increases in drivers mostly agreeing to certain social indicators, such as knowing fleet managers who are considering transitioning or business leaders talking about transitioning. Both questions saw “mostly agree” responses increase five-fold. Responses of “mostly agree” to the statement ‘that range was sufficient to complete most daily trips’ increased six-fold.

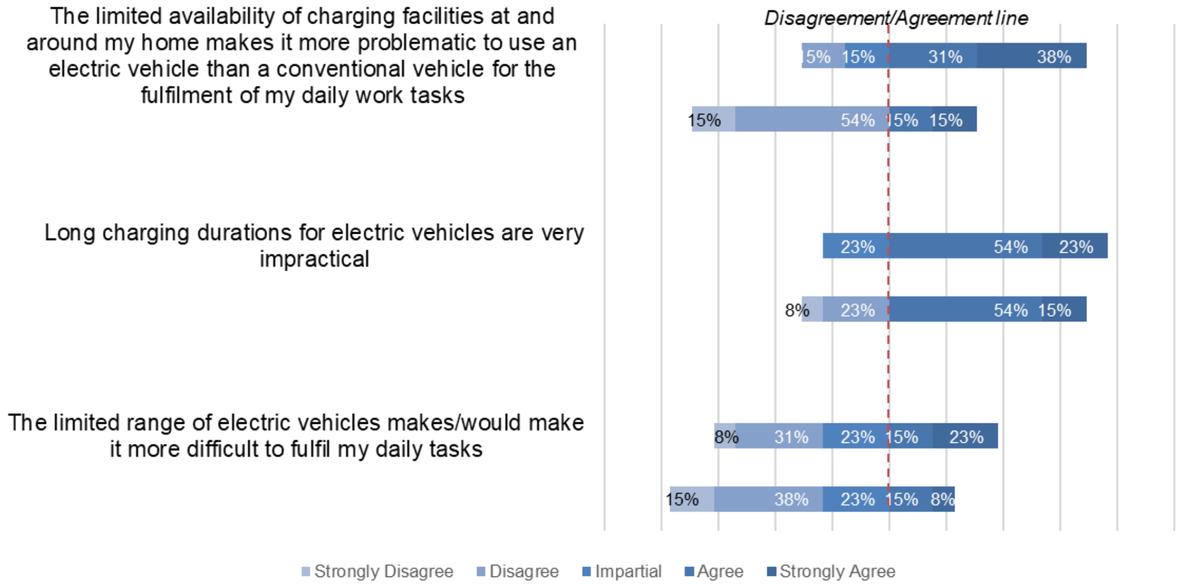
Figure 91 – Social Influence results of the 13 Transitioned Drivers



4.2.2.5.4 Effort Expectancy

There were also improvements on the perceptions of the amount of effort required for EVs (Figure 92). Out of the 13 respondents who transitioned to EV since the first survey, only 30% continued to see limited availability of charging as a problem, compared to 69% when driving an ICEVs. Perception of range has also improved: 23% seeing it as a limitation to their daily work compared to 38% when driving an ICEVs. However, this shift in opinion was less significant than seen in the areas of Adoption Intentions and Performance Expectancy.

Figure 92 – Effort expectancy of the 13 Transitioned Drivers



4.2.2.6 Key learnings

After drivers have tried EVs, they tend to feel more positively about the technology

The experience of driving an EV significantly improved drivers' perceptions of EVs, with the most notable shifts in opinion being seen for Adoption Intentions, Performance Expectancy and Social Influence. The positive shift in perception of EVs amongst the new 13 EV drivers was substantial, and this creates a positive outlook for EVs, since it is likely drivers may prefer EVs once they are given an opportunity to try them.

There is some scepticism about the robustness of technologies associated with EVs, with negative feelings about range and smart charging being common

There was not universal confidence in EVs amongst the British Gas engineers. Reassurance and consistent communication about the potential and robustness of the technology may be needed in order to ensure drivers are comfortable with adopting EVs and do not dismiss the technology before trying it themselves.

EVs can offer significant value for drivers as well as the environment, making the business case for transition even stronger

EVs can provide significant value to drivers and make their working lives easier. There were overwhelmingly positive beliefs about the performance of EVs when compared to ICEVs. Amongst the EV driver population in the second survey, 95% had positive attitudes towards the acceleration and quietness of the vehicles, and 76% said that EVs could save them time at work by allowing them to charge when they are not working.

4.2.3 Uber

4.2.3.1 Overview

The Uber behavioural research questionnaire was distributed to Uber drivers in London through a mailing list. The first iteration was distributed in May 2021, and the second in December 2021 (Table 38). An incentive was offered to encourage responses. In total, 1,750 responses were recorded and analysed, of which 169 responded to both the first and second iteration; 459 (26%) were EV drivers. The 10-minute survey analysed the attitudes of Uber drivers towards EVs, and their adoption intentions in the coming years.

4.2.3.2 Descriptive statistics

1,750 questionnaires were completed by Uber drivers over two iterations. 169 of these answered both the first and second survey. Of the 1,750, 459 were EV drivers, with the remaining being ICEV or hybrid drivers (Figure 93). Demographics were predominantly male (96%), of median age 35-44.

Of the Uber drivers surveyed, two thirds drive more than 90 miles per day, with 84% driving 67 miles or more. 62% of drivers said the maximum distance in a day would exceed 120 miles (Figure 94).

Table 38 – Details of Uber behavioural survey

	First iteration	Second iteration
Distribution Period:	19/05/2021 → 20/05/2021	01/12/2021 → 09/12/2021
Distribution Method:	Uber via newsletter	Uber via newsletter
Total Responses:	798	952 (66 duplicates excluded)
EV Responses:	**71** (3% total EV fleet)	**388** (~10% total EV fleet)
ICEV Responses:	**727** (91% of total responses)	**564** (58% of total responses)
Demographic:	**95%** Male Median Age of **35-44**	**97%** Male Median Age of **35-44**
Returning Respondents:	Overall, 169 drivers responded to both surveys. Further analysis will reveal changes in attitudes specifically for these responses.	

Figure 93 – Vehicle types driven by respondents

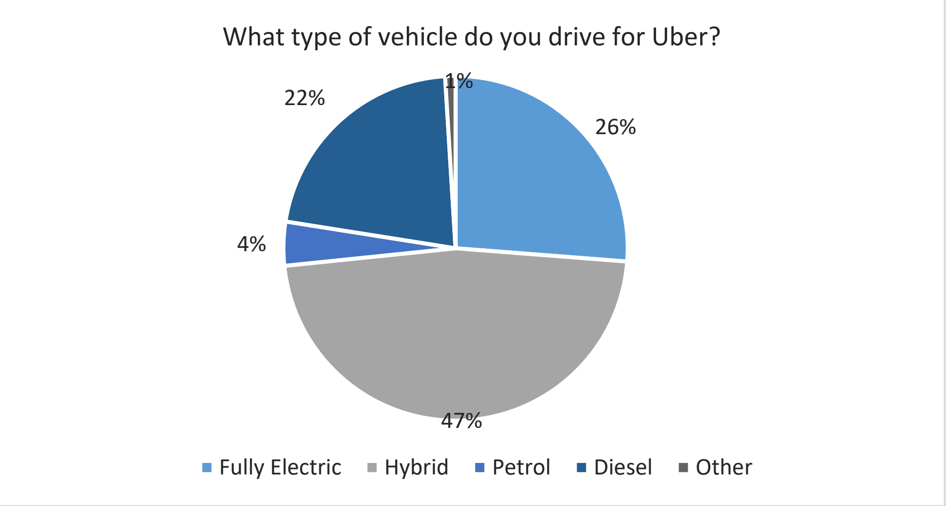
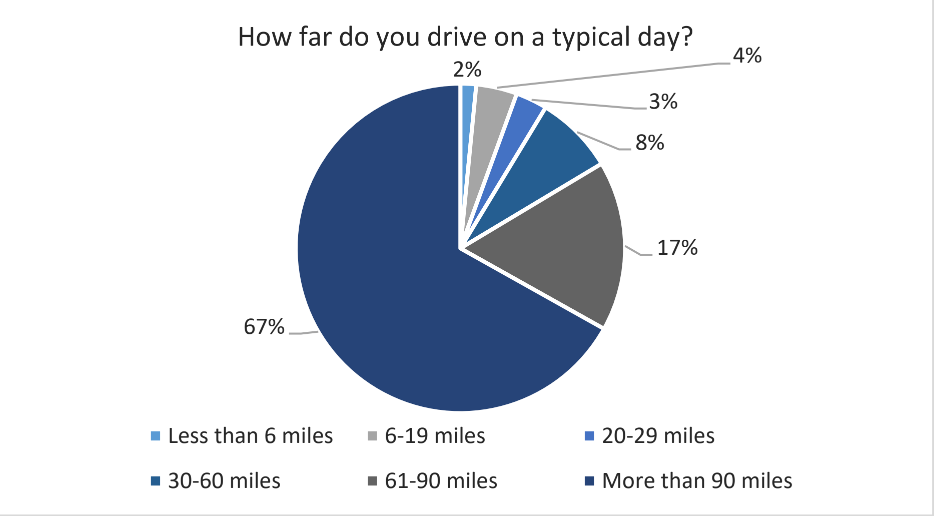


Figure 94 – Distances driven by respondents

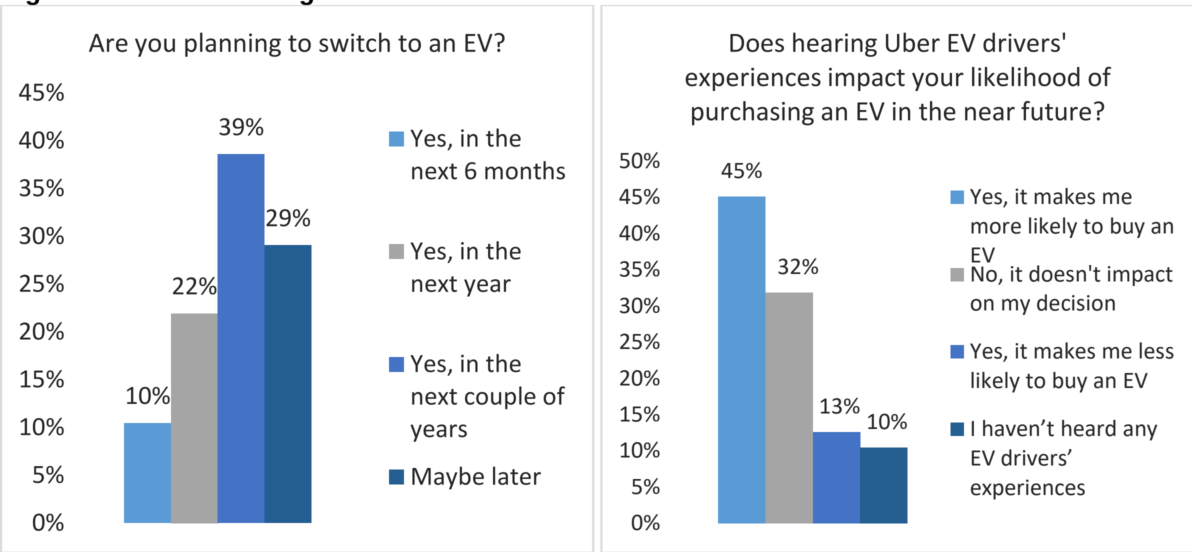


4.2.3.3 Results

4.2.3.3.1 Adoption intentions

Attitudes towards EVs and perceptions of their performance are largely positive (Figure 95). 71% of non-EV drivers state that they are planning to switch to an EV, with 10% planning to make the switch within the next six months. Sharing experiences between EV and non-EV drivers has a moderate impact on non-EV drivers' likelihood of switching to EV, with 45% of these saying it will make them more likely to do so. Only 13% state it would make them less likely to switch to an EV, suggesting some negative opinions. Furthermore, 10% of non-EV drivers stated they have not heard of any EV drivers' experiences, suggesting there is communication between Uber drivers which may impact the decision on electrification. Positive perceptions and experiences are therefore necessary to encourage EV adoption among the PHV fleet in London.

Figure 95 – EV switching intentions



4.2.3.3.2 Charging behaviours

4.2.3.3.2.1 Home charging and public charging

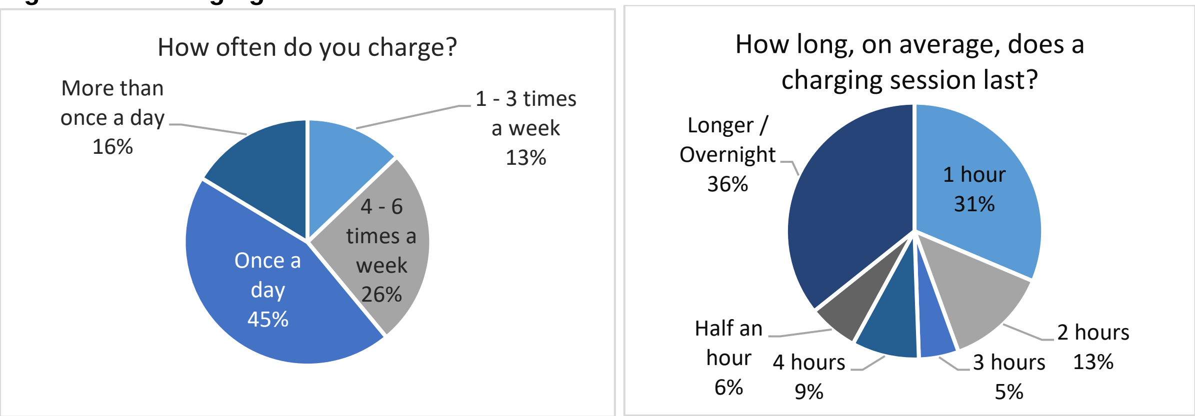
The majority of Uber EV charging occurs at public charge-points. As the demographic of PHV EV drivers changes from early adopters to the majority, following Rogers' diffusion of innovation model[22], the percentage of drivers with off-street parking and home CPs installed will decrease. Currently:

- 11% of EV drivers who have a home CP exclusively charge at home, meaning a large majority charge in a public location – around 80% of total energy used.
- 37% of the EV drivers who charge with a home CP have changed their electricity tariff, suggesting that most EV drivers may not be receiving the best value of EV charging as well as not engaging in smart charging.

Figure 96 shows that most drivers (61% over both surveys) charge once a day or more. Charging sessions are mostly one hour or longer/overnight, suggesting that the shorter sessions are 'on-shift' 'top-ups' on rapid CPs while longer sessions are 'on-street' CPs at night, 'off-shift'. Preferred charging speed was predominantly rapid and ultra-rapid, with the latter becoming more popular in the second survey based on the roll-out of new CPs in London and driven presumably by the desire to reduce the opportunity cost of charging over driving.

[22] Rogers, E.M. (1962) *Diffusion of Innovations*. Free Press of Glencoe.

Figure 96 – Charging behaviour



Around a fifth of EV drivers are developing experience and familiarity in finding CPs. However, the majority use software to decide which charging station to utilise. Charging network loyalty is low, with around 30% of EV drivers sticking to a specific network when charging in public during shifts. On-shift charging seems to be opportunistic rather than pre-planned or driven by low state of charge, suggesting that range anxiety is not a significant issue. Only ~15% of EV drivers plan their charging into pre-planned stops such as lunch. This has implications on the predictability of PHV charging behaviours in London, and other cities across the UK, as charging locations and timings are not based on habit.

4.2.3.3.2.2 Charging cost, availability and reliability

Just over half of EV drivers agree that the cost of using public CPs is reasonable. However, reliability remains an issue, with 31% of EV drivers stating that charging stations are unreliable. Given the high utilisation of public CPs and the opportunity cost for drivers, this is an important aspect to correct in order to maintain positive opinions among PHV drivers.

4.2.3.3.3 Barriers to EV adoption and Effort expectancy

The purchase price of EVs is seen as the main barrier to EV adoption for Uber drivers: 73% of respondents, who do not yet own an EV, state that too high a purchase price has a high or very high effect on their choice of vehicle. This is followed by:

- Insufficient access to charging, both at home and in public: half of non-EV drivers rated these as a significant barrier respectively
- Vehicle purchase price is an important factor for Uber drivers, who often purchase second-hand vehicles to lower the initial CAPEX
- Access to vehicle financing options was cited as an issue for just under half of drivers.

The awareness of TCO calculations and incentives may be a good solution for transitioning cost-conscious PHV drivers to EVs.

Effort: range anxiety remains an issue for most drivers: 64% agreed that it would make it more difficult to fulfil their daily tasks, while 75% stated that long charging durations would be an issue. More than three quarters of drivers agreed that limited availability of EV charging infrastructure makes it problematic to use an EV for their role. This is consistent with the TCO findings on the opportunity cost of charging and the importance of the availability of functioning rapid and ultra-rapid CPs within the city.

4.2.3.3.4 Organisational factors

Opinion on support from Uber is largely positive and split evenly amongst EV and non-EV drivers. A high level of impartial responses suggests some drivers are not aware of the organisational efforts towards EVs or have no opinion on the way this is managed.

4.2.3.3.5 Performance Expectancy

75% of non-EV drivers agree that driving EVs will improve air quality and be beneficial to the environment, compared to 87% of EV drivers. Despite the difference between the two groups, it is clear that Uber drivers recognise the environmental benefit of switching to EVs and it is likely there will be further support from this group.

EV drivers are very positive about their driving experience and acceleration: 90% approve of the acceleration performance and enjoy the lack of engine noise. While more than half of non-EV drivers shared this opinion, the average was closer to 60% compared to 90%. As EVs become more widespread and OEMs focus production on new EV models, it is likely that opinions of non-EV drivers will start to converge with their EV colleagues regarding vehicle performance.

4.2.3.3.6 Qualitative comments

An open-text section allowed survey respondents to leave their opinions on EVs in general. Keyword frequency was used to identify key trends in the comments, while maintaining the anonymity of respondents. ‘Charging’, ‘Range’, and ‘Cost’ were main themes, with comments clarifying the barriers to adoption: lower purchase price, easier and quicker charging, and higher range; all were repeatedly requested by Uber drivers.

4.2.3.4 Key learnings from the results

Reliable public charging infrastructure is critical for the adoption of EVs among PHV drivers

There is a strong reliance on the public charging network: only 28% of early adopters use a home CP, and often ‘top up’ with public CPs. Range anxiety remains a predominant barrier in EV adoption, with a significant amount of both EV and non-EV drivers citing CP availability and reliability as an issue. Rapid and ultra-rapid CPs are strongly preferred, presumably due to the lower opportunity cost (see Uber TCO section).

PHV charging behaviour in London remains difficult to predict as EV charging locations and timings are not based on habit

Early EV adopters tend to charge as and when needed, rather than in pre-planned breaks. Little consideration is given to charging network and location.

Main barriers to EV adoption for non-EV drivers are both financial and operational

High purchase price was the greatest barrier to EV adoption, with references to difficulties in accessing finance. Operationally, access to home and public CPs was a main concern.

Positive attitudes suggest a willingness to change once concerns are addressed

Respondents showed a strong interest in EVs, with non-EV drivers recognising the performance of EVs in acceleration and pleasantness to drive.

4.3 Further analysis of the results of the behavioural surveys

This section summarises the additional analysis of the survey data carried out by Imperial College Consultants to complement the descriptive analysis of the statistics in the previous pages. The questionnaires were designed using the FAST (Firm Adoption of Sustainable Technologies) framework (introduced in Section 4.1) and this is utilised here in exploratory factor analysis (EFA). This analysis was performed to understand the level of correlation among the attitudinal statements contained in the survey and to identify the underlying latent factors (or variables) characterising the respondents.

The following sections describe this methodology and present additional analysis using the factor analytical approach to combine the responses to a wide range of Likert-scale type attitudinal questions. Insights and implications of this analysis for EV transition for Centrica, Uber and Royal Mail are presented, followed by an analysis of cross-fleet similarities and differences.

4.3.1 Factor Analysis of Likert-scale Type Questions

4.3.1.1 Background

Since ordinal data from discrete items were investigated, exploratory factor analysis (EFA) was performed to understand the level of correlation among the attitudinal statements contained in the survey and to identify the underlined latent factors (or variables) characterising the respondents. The latent factors are not directly measurable by the analyst. Therefore, EFA helps understand by which statements they are manifested and to what extent (and in which direction) they influence the factor. Insights generated from this analysis can confirm whether the framework was appropriate and a ‘good fit’ for the application domain, and extract which underlying aspects that influence the respondent’s perspective are particularly critical. This can then be used to design interventions by deciding where to focus on, and which aspects are less relevant in shaping the overall views. It should be stressed that the EFA is complementary to the descriptive statistics that are based on the same data sets. Where the descriptive statistics cover the responses to individual questions and variation amongst the responses, the factor analysis looks at the relationships and how various questions can be combined to study correlated variability and to determine to what extent they can be associated with a common factor (or theme).

4.3.1.2 Factor Analysis methodology

EFA was undertaken with the entire set of attitudinal questions for each of the three fleets: Centrica, Uber and Royal Mail. Additional analysis on the Novuna customers can be done similarly. When performing the analysis, it was first decided to perform the EFA separately per fleet and for each iteration separately. This was done for two reasons:

- Some information is lost as the iterations have, in certain cases, different statements and different missing values, which need to be excluded to run the EFA
- Combining the two iterations will not help find the correlation between the two iterations. When combined, EFA would treat the iterations as a single block of responses, so changes in attitude between these iterations would not be found.

The survey contained questions designed to explore the FAST framework. Rather than undertaking a factor analysis within each block of questions characterising each FAST construct, it was decided to undertake a factor analysis with the entire set of questions (for each fleet) and let the data and analysis lead to the identification of the factors.

This multiple-item investigation, through different constructs, was carried out in order to identify the latent variables that are only observable with the help of the factor analysis[23]. This analysis, undertaken on the whole set of attitudinal items, has two benefits that help define a more precise latent variable. First, it confirms the correlation inside the constructs as in the previous literature[24] and to obtain a more concise number of items defining the latent construct. Second, it enables investigation of the possible correlation among the constructs.

A rigorous statistical procedure was undertaken in order to evaluate the reliability of the survey dataset by applying the factor analysis correctly and to determine suitability of the method. This analysis found a high sampling adequacy across the surveys – further details can be found in Appendix 9.3.

4.3.1.3 Interpreting the EFA results

Factor *loadings* show the variance explained by the statement on that particular factor and can be seen as the correlation coefficients between statements and factors. When comparing different cases to decide the best number of explained factors, it is important to find a balance between the variance explained by each solution (the more factors extracted the higher degree of variance explained) and the parsimony of the solution (i.e. avoiding solutions with an excessive number of factors that are not highly loaded or only highly loaded by one variable)[25]. Taking into account this trade-off, the best factor solutions were identified considering factor loadings equal to or higher than 0.4. Note that semantically positive and negative statements have a different direction and, therefore, opposite loading signs.

After the factor analysis of the fleets individually, a cross-fleet analysis is performed considering two types of clustering:

- those with first-hand experience driving an EV and those without, combining statements that are consistent throughout the three fleets
- those who would recommend EVs to colleagues or others, and those who would not recommend them. This analysis only considers those statements that all questionnaires have in common.

The radar/spider web charts display the factor loadings graphically for each of the identified factors. On the outside of the circle, the identifiers of the statements are shown (two letters corresponding to the FAST constructs followed by a number) which refer to the statements in Table 33. Each of these variables get its own axis running as a spoke from the centre to the outside of the chart. The spokes on the chart display the relevant value range (between -1 and +1 with a solid circle indicating the 0, 0 and +1, or -1 to 0, or using smaller highs and lows where applicable given the spread of the data). The range is shown at the vertical axis from the centre of the circle to 12 o'clock. The numbers visualised are taken directly from the

[23] Fabrigar, L. R., Wegener, D. T., MacCallum, R. C., & Strahan, E. J. (1999). Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods*, *4*(3), 272–299. and Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric Theory* (3rd ed.). McGraw-Hill.
[24] Mohammed, L., Niesten, E., & Gagliardi, D. (2020). Adoption of alternative fuel vehicle fleets–a theoretical framework of barriers and enablers. *Transportation Research Part D: Transport and Environment*, *88*, 102558.
[25] Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2007). *Using multivariate statistics* (Vol. 5). Pearson Boston, MA.

relevant table with factor loadings, and highlight a single column from those tables. These figures show which of the statements load for the factor listed in the caption, what the values are, how these compare to other relevant statements, and how they changed between iterations. Points on adjacent spokes are connected with a line to aid in the relative comparison of the variables, as differences are made apparent by the shape and size of the polygons.

4.3.1.4 High-level Factor Analysis results by fleet

By looking at the statements with similar factor loadings and exploring their semantics, it can be seen that five common factors explain the different main tendencies in the different fleets and iterations while one more factor is identified for Centrica, iteration two, given some extra statements presented to the respondents.

Table **44**, Table 45 and Table 46 in Appendix 9.4 show the EFA results for Centrica, Uber and Royal Mail respectively. In general, across the fleets and iterations, the following six latent factors are characterised by some common statements which can also be recognised from the FAST framework (in brackets):

- **Benefits of EV to the organisation:**
    - Thinking that EVs would be beneficial to the environment in the long term (*FAST: Attitudes/emotions & social influence*)
    - Thinking that EVs would eventually result in cost savings in respondent's industry (*FAST: Attitudes/emotions & social influence*)
- **Compliance to external expectations:**
    - Companies within the respondent's industry are considering EVs (*FAST: Attitudes/emotions & social influence*)
    - Business leaders in respondent's industry are talking about switching to EVs (*FAST: Attitudes/emotions & social influence*)
    - Policy makers expect companies in respondent's industry to switch to EVs (*FAST: Attitudes/emotions & social influence*)
    - Customers expect organisations in respondent's industry to switch to EVs (*FAST: Attitudes/emotions & social influence*)
- **Impact of transport electrification on work tasks:**
    - The limited range of EVs makes/would make it more difficult to fulfil my daily work tasks (*FAST: Effort related to EV adoption*)
    - Long charging durations for EVs are very impractical (*FAST: Effort related to EV adoption*)
- **Considerations of the drivers' perspective from decision-makers in the organisation:**
    - Shift to EVs is supported by sufficient information and training provided by our organisation (*FAST: Management involvement and training*)
    - Managers implementing strategies and technologies to ensure that the switch to EVs has minimal impact on our tasks (*FAST: Management involvement and training*)
- **Opinion of EV drivers on the driving experience with their vehicle:**
    - Driving an EV is more pleasant as it is less noisy than a conventional vehicle (*FAST: EV performance*)
    - The acceleration performance of the EV is very good (*FAST: EV performance*)
- **Pro-smart charging, supportive views on smart charging (only Centrica, iteration 2):**

- Smart charging is risky – there may not be enough charge when the driver needs it (*FAST: Effort related to EV adoption*)
- Smart charging saves British Gas money (*FAST: Attitudes/emotions & social influence*)
- Overall support to the rollout of smart charging across our electric fleet (*FAST: Attitudes/emotions & social influence*)

Table 44, Table 45 and Table 46 also show that the identified latent factors mainly correspond to the FAST constructs, confirming the framework was suitable for the study. Apart from the common statements across fleets and iterations, some of these factors are also characterised by other statements, that are different depending on each case, and come from different FAST constructs.

4.3.2 Results and discussion of Factor Analyses for each fleet

Building on the factor analysis performed and the data in Appendix 9.4 for the individual fleets, the following sections discuss the implications of the findings. For each fleet, there is a discussion based on the overall analysis of the table, for that fleet, as well as the changes between the iterations per factor, as displayed in the radar/spider web charts. After a discussion of the three fleets individually, results of a cross-fleet analysis are shown.

4.3.2.1 Discussion of the Royal Mail results

The EFA on the statements regarding Royal Mail drivers also identified the same five factors for both iterations namely: ‘Benefits of EV to the organisation’, ‘Compliance to external expectations’, ‘Impact of electrification on work tasks’, ‘Considerations of drivers' perspective’, and ‘Opinion on driving experience’. The factors characterising iteration one and iteration two are also consistent. No significant changes can be observed in the statements associated with the latent factors, but the loading of some individual statements can change as discussed below.

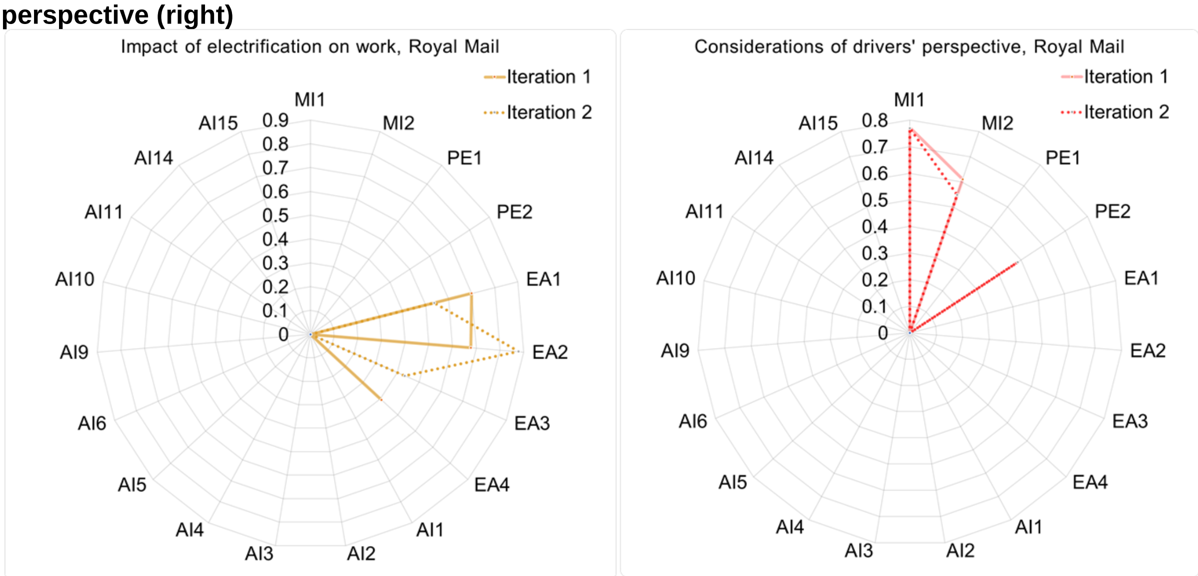
The radar chart below (Figure 97, left) shows the factor loadings characterising the factor “Benefits of EV to the organisation”. This is mainly explained by the statements AI2 and AI3. All the benefits related to both cost and environment appear to be clear since the beginning of the study. In iteration two, the opinion on EVs being a temporary phenomenon (AI5), which was negatively correlated in iteration 1, is not significant anymore (as in the Uber case).

Figure 97 – Royal Mail – Benefits of EV to the Organisation (left) Compliance to External Expectations (right)

The second factor "compliance to external expectations", shown in Figure 97 (right), has similar loading for all the statements concerning the drivers' understanding regarding the consideration that EVs have in both private and public domains (AI14, AI11 and AI10). Opinion on the positive impact on public image of the companies with EVs (AI9) becomes the statement with a greater explanation of variance in iteration two, that is the most important explaining the factor even though it already played a key role in iteration one already.

The third factor "Impact of electrification on work tasks" (Figure 98, left) is strongly related to three statements EA1, EA2, EA4 in iteration one while, in iteration two, EA4 is replaced by EA3. This is consistent with the analysis of the other fleets, suggesting availability of charge points is the key factor now rather than remembering to plug in as drivers got more familiar with the process. Challenges with the availability of charging points could be related to an increase in the number of EVs without sufficient additional charging capacity provided.

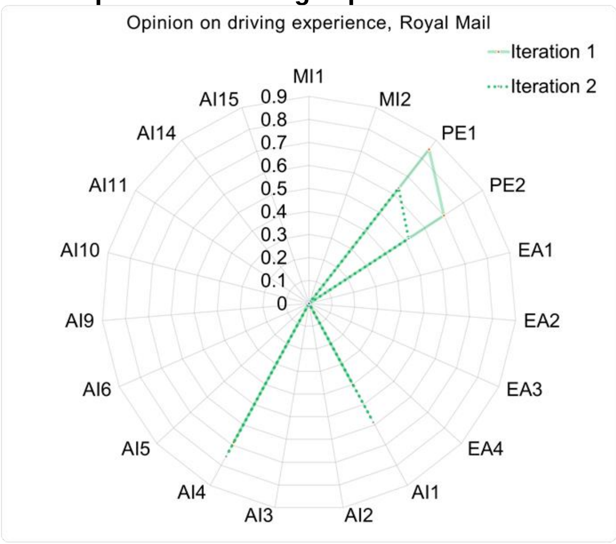
Figure 98 – Royal Mail – Impact of electrification on work (left) consideration of drivers' perspective (right)



The fourth factor “considerations of drivers' perspective” shown above in Figure 98 (right) is exactly characterised by the two statements MI1 and MI2. The loading with greater magnitude is of the statement MI1 which suggest that in the drivers’ perception, the company provides sufficient information and training to allow a smooth transition to EVs. No changes in the loading can be observed between iterations. In iteration two the statement PE2, regarding acceleration of EVs, explains some of the variance related to the latent factor on drivers’ perspectives. This could perhaps be interpreted as drivers recognising that the type of vehicle used in the fleet, as chosen by management, responds well to their interest and needs for the job. The acceleration could also be particularly relevant as Royal Mail drivers need to stop and start frequently, rather than drive longer distances at a constant speed, and possibly was used as one of the main benefits in communication from management.

The fifth factor “opinion on driving experience”, shown in Figure 99, is manifested specifically by two statements with greater impact: PE1 and PE2. This suggests a positive perception on the EV characteristics, specifically about noise and acceleration. Furthermore, the driver’s opinion is also influenced by the interest in EV in general (AI1) and the perception that EVs are cool and pleasant to drive (AI4), AI1 to a lesser extent.

Figure 99 – Royal Mail – Opinion on driving experience



Key insights:

- The benefits related to both cost and environment seem to be clear since the beginning of the study, and the consideration that EVs are only temporary is not significant anymore for the impact on Royal Mail.
- There are only minor variations on "compliance to external expectations”, with the statement “companies who have electric vehicles have good public image” becoming the one with a greater explanation of variance in iteration two.
- Access to charging points has become a key area of concern in iteration two, where it was not the case for the first iteration. For the first iteration, the impact on work tasks was linked to range and remembering to plug in at the end of a shift. After becoming more familiar this concern disappears. Charging time remains the topic which most explains impact of EVs on the job.
- Little changes between iterations related to the consideration of the driver's perspective in decision making, though vehicle performance plays a small role in iteration two suggesting that the vehicle is a good fit for the needs of the drivers.

- Driving experience is manifested by statements on vehicle performance as well as attitudes/emotions, with positive perception on the EV characteristics. Vehicle noise and acceleration become slightly less important, relatively to the other statements, in the second iteration.

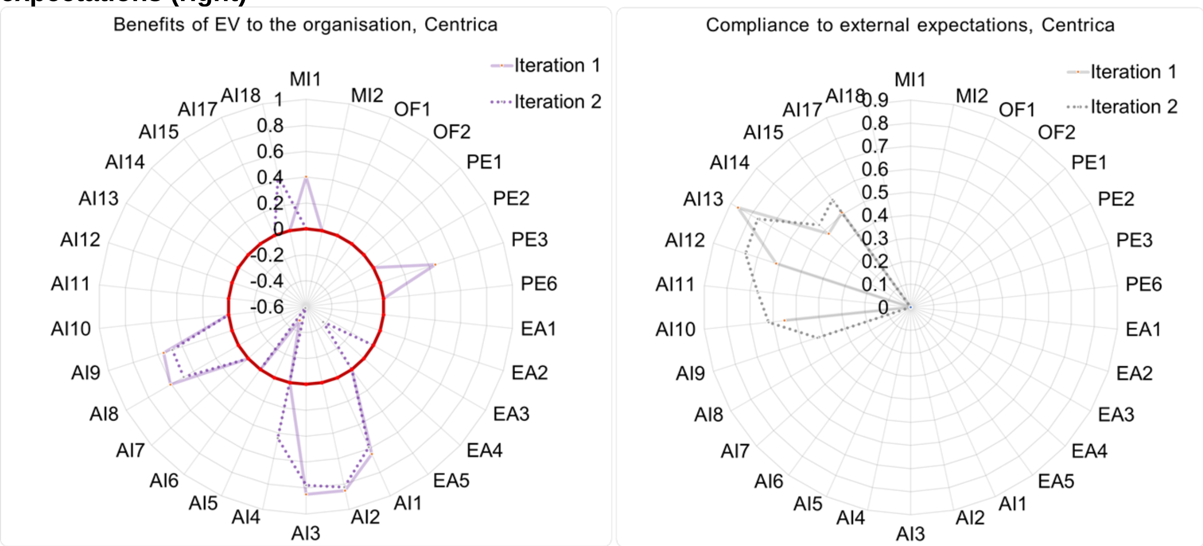
4.3.2.2 Discussion of the Centrica results

The EFA on the statements that were presented to Centrica employees identified five factors for iteration one namely: ‘Benefits of EV to the organisation’, ‘Compliance to external expectations’, ‘Impact of electrification on work tasks’, ‘Considerations of drivers' perspective’, and ‘Opinion on driving experience’, with six factors for iteration two (with the addition of pro-smart charging) given the addition of four statements in the second iteration of the questionnaire. No significant changes can be observed in the statements associated with the latent factors; however, some statements can be different.

The variance of the factor “benefits of EV to the organisation” (Figure 100, left) is mostly explained by statements AI1, AI2, AI3 and AI8. This shows a good understanding of benefits for the organisation across drivers. The factor “benefits of EV to the organisation” is also influenced, but to a lesser extent, by variables related to the FAST constructs *Management and Training* as well as *Electric Vehicle Performance* for iteration one.

Having to remember to plug in might reduce the EV benefit for drivers who are concerned about this – observed by the negative value on statement EA4, consistent throughout the two iterations. Statement PE3 instead shows a change in belief regarding charging habits: in the second iteration, the statement: “The fact that electric vehicles can be charged overnight saves working time as it avoids fuel station trips” is no longer significant. This could be linked to some EV drivers being unable to charge at home and thus using the public charging network.

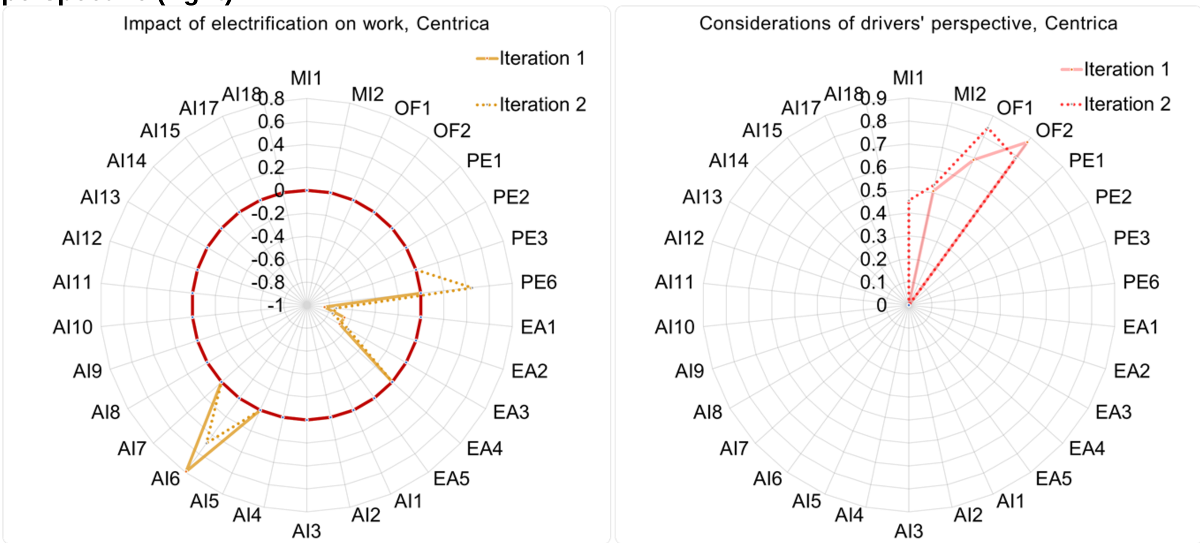
Figure 100 – Centrica – Benefits of EV to the organisation (left) compliance to external expectations (right)



In the second factor “compliance to internal expectations” (Figure 100, right), drivers are aware of the move to transition to EVs by government (AI13) and other businesses (AI12), and that EV adoption impacts the reputation of their business. Between the two iterations this view of the positive reputational impact of EVs has increased, with more drivers believing that EVs are viewed favourably (AI11) and give companies a good public image (AI9).

The third factor, "impact of electrification on work tasks" (Figure 101, left), demonstrates that across both iterations there are a variety of views amongst drivers. While many drivers find EV range sufficient (AI6), some drivers do have concerns over the practical difficulties resulting from vehicle range (EA1) and CP availability (EA2).

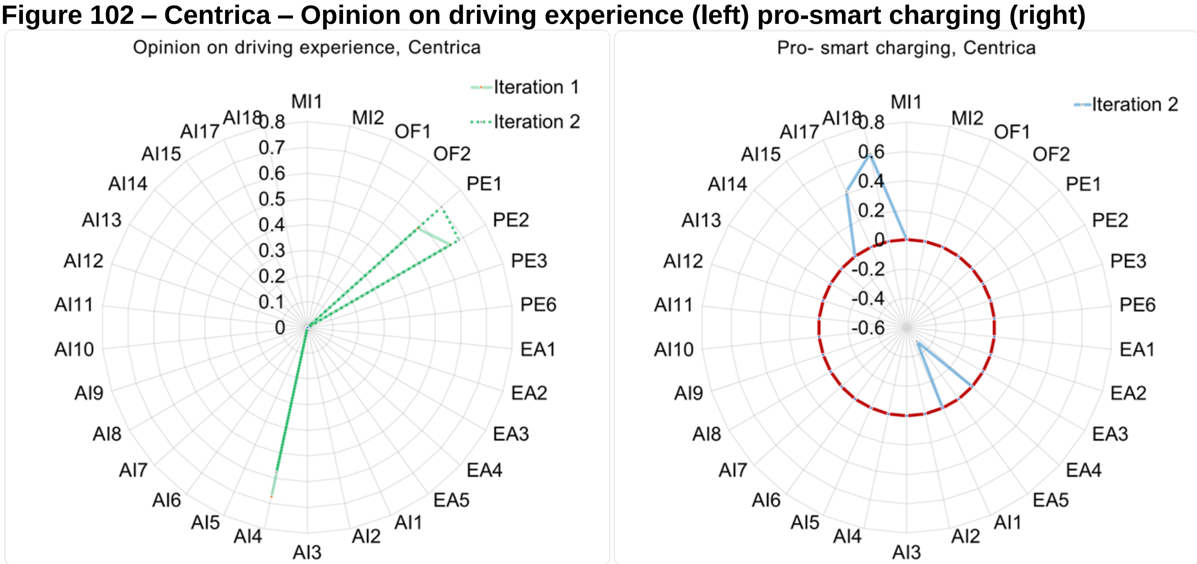
Figure 101 – Centrica – Impact of electrification on work (left), considerations of drivers' perspective (right)



The fourth factor "Consideration of drivers' perspectives" (Figure 101, right) shows that information seems to be communicated effectively to the drivers and that they feel they are properly consulted by the company.

The fifth factor, "opinion on driving experience" (Figure 102, left), shows positive perceptions relating to EV characteristics, specifically about noise (PE1), acceleration (PE2) and driving experience (AI4) which are based directly on the driver's experience. While these views might be subjective, they show that the right choice of vehicle is an important part of getting the drivers on board with the transition to EVs, and that driver experience should be considered alongside cost and operational factors when choosing vehicles.

Figure 102 – Centrica – Opinion on driving experience (left) pro-smart charging (right)



The ‘Pro-Smart charging’ factor (Figure 102, right), which only applies to Centrica’s second survey iteration, demonstrates an overall positive view of smart charging (AI18) and the potential financial savings (AI17), although some drivers expressed concern over the risks that it may impact their ability to drive when needed (EA5). Good communications about smart charging strategies and any safeguards in place might be useful to reduce those concerns.

Key Insights:

- The factors characterising both iterations are consistent for Centrica, with only minor variations.
- There is a good understanding of the benefit of EVs for the organisation across drivers
- Some small changes can be observed on the influence of charging, possibly linked to new habits or better understanding
- Drivers perceive the interests of both private and public stakeholders on the EV transition and recognise the impact of these views on the expectations for the organisation, and this seems to be improving
- In both iterations, the drivers have concerns on charging range and CP availability and recognise that practical difficulties could influence their ability to do the job with an EV. Views related to effort of using an EV, attitudes/emotions to sustainability, and vehicle performance all influence the impact on work to some extent.
- The driving experience is shaped mostly by noise, acceleration, and how ‘cool’ the EV is perceived. Little changes in between iterations.
- Drivers think that smart charging can lead to monetary savings, but have concerns about having sufficient charge left. Good communications about smart charging and constraints set for a minimum state-of-charge at the start of a shift are key.

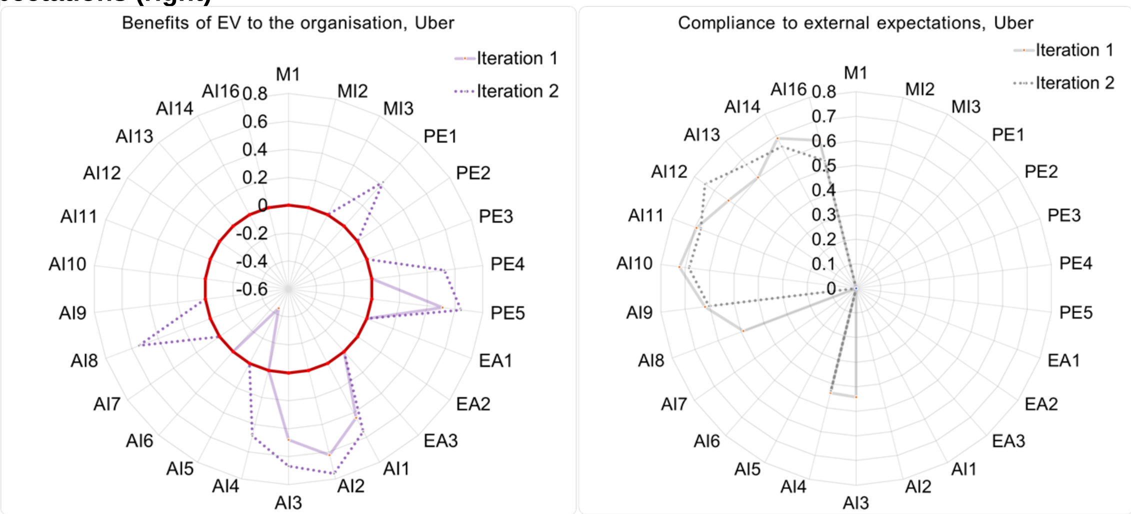
4.3.2.3 Discussion of the Uber Results

The EFA on the statements that were presented to Uber drivers identified five factors for both iterations, namely: ‘Benefits of EV to the organisation’, ‘Compliance to external expectations’, ‘Impact of electrification on work tasks’, ‘Considerations of drivers' perspective’, and ‘Opinion on driving experience’. The factors characterising both iterations are consistent and no significant changes can be observed in the statements associated with the latent factors, but some statements can change. This is most notable for opinion of driving experience, and benefits to the organisation.

Figure 103 (left) suggests the drivers have a positive view on the environmental impact and a pro-environmental attitude among the other benefits for the organisation. It also shows that the benefits to the organisation are not linked to just one aspect of the FAST framework (AI2, AI3, PE5).

All the benefits related to cost and environment appear to become clearer over time between the iterations. Because Uber drivers own their own vehicle, which they use to provide transport service on behalf of the organisation, the benefits to the organisation factor can also be interpreted as directly being advantageous to the driver and their ability to earn a living with their car. This factor could therefore also be considered as “benefits of EV to the Uber driver”.

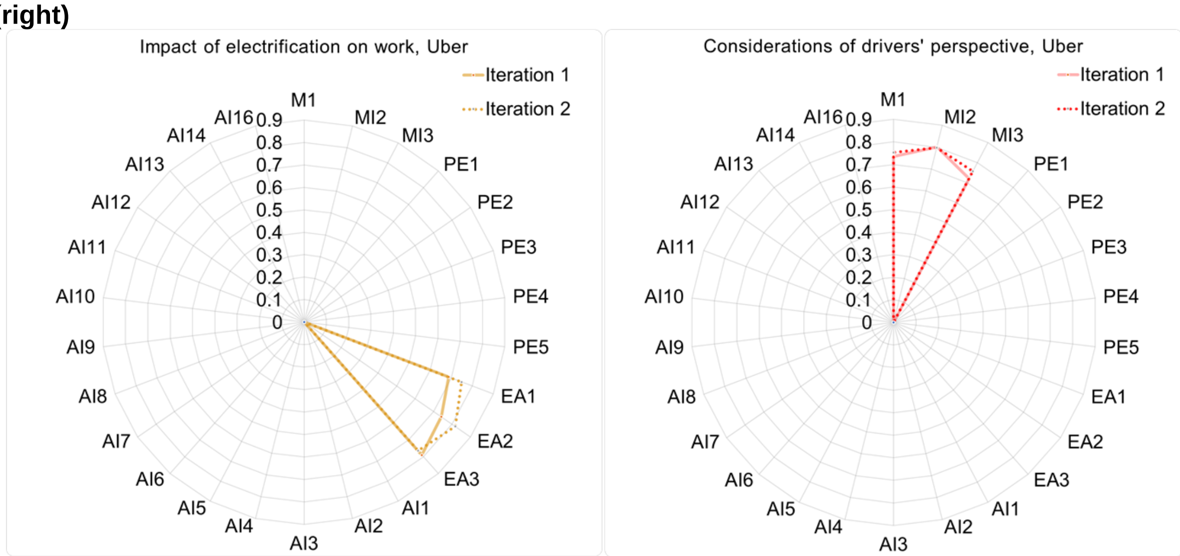
Figure 103 – Uber – Benefits of EV to the Organisation (left) compliance to external expectations (right)



The second factor, “compliance to external expectations”, shown in Figure 103 (right), is only associated to the *FAST construct “Attitudes/emotions & social influence*” with very similar loading for all the statements concerning the drivers’ understanding regarding the consideration that EVs have in both private and public domains such as AI10, AI13, AI11, and AI12. This shows that drivers have a good awareness of the overall direction the industry and policy makers are taking, and how this will shape their own transition.

The third factor, “impact of electrification on work tasks” (Figure 104, left), exactly corresponds with the three statements characterising the effort related to EV adoption of the FAST framework in both iterations, namely through EA1, EA2, and EA3 regarding range, charging duration and charging facilities respectively. This confirms that these issues are of particular concern for the Uber drivers, and they recognise that difficulties with charging will influence their work directly and show a good fit of the FAST framework in understanding these attitudes. Although these statements are semantically negative, their loading factors are all positive as they are all contributing to the factor in the same direction. There are no clear differences between the first and second iteration, indicating this is an ongoing concern for Uber drivers despite increases in available public CPs throughout 2021 (ZapMap, 2022).

Figure 104 – Uber – Impact of electrification on work (left) consideration of drivers’ perspective (right)

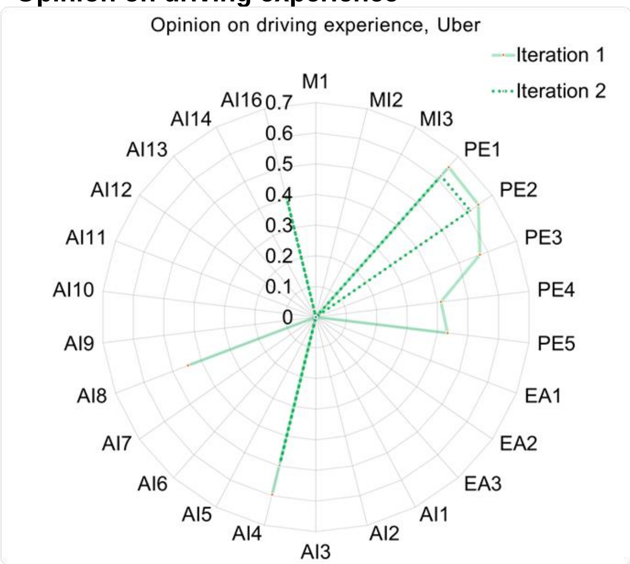


The fourth factor, "considerations of drivers' perspective", shown in Figure 104 (right), is exactly characterised by the statements of the FAST construct: *Management involvement and training*. The loading with greater magnitude is of the statement "Uber are implementing strategies and technologies to ensure that the switch to EVs has minimal impact on our tasks" (MI2) showing that in the drivers' perception the company is working on a smooth transition to EVs, and that these decisions are linked to the experience of the driver themselves. However, there are no noticeable differences between both iterations in the loading of statements on this topic.

The fifth factor, opinion on driving experience (Figure 105), the two statements with greater impact are about the pleasantness of driving an EV due to lack of noise (PE1), and the acceleration performance of EVs (PE2). This suggests positive perception on the EV characteristics regarding noise and acceleration. The driver's opinion is also influenced by the perception that EVs are 'cool and pleasant' to drive (AI4 -*FAST: "Attitudes/emotions & social influence*"). This is presumably not only linked to the driver themselves, but also to the comfort of their passengers. This can be part of a positive experience and might differentiate drivers with an EV from their colleagues.

The statement: "The fact that the electric vehicle can be charged overnight saves working time, as it avoids fuel station trips" (PE3) no longer loads any factor in iteration two. This might be related to a better understanding of the charging events and charging availability, or an adjustment of expectations related to availability of home overnight charging compared to on-shift public charging, which is seen as an opportunity cost.

Figure 105 – Uber – Opinion on driving experience



Key insights:

- The changes in the factor analysis between iterations are most prominent for opinion of driving experience, and benefits to the organisation
- EV benefits related to cost and environment appear to become clearer over time between iterations, which are more aligned to benefits to the organisation. Benefits to the organisation is a more difficult construct for Uber, given the role of the driver. Relevant statements include those on EV performance as well as attitudes/emotions. Drivers have positive views on sustainability.

- Drivers have a good awareness of the overall direction the industry and policy makers are taking, and how this will shape their own transition.
- Charging is an ongoing concern and drivers recognise that difficulties with charging will influence their work directly, with no clear differences between the first and second iteration.
- The company is working on a smooth transition to EVs in the drivers' perception
- EV drivers positively rate their vehicle and driving experience (also for their passengers) which is shaped by acceleration, noise, and social influence. The statement: "The fact that the electric vehicle can be charged overnight saves working time, as it avoids fuel station trips" no longer has a correlation with the driving experience. This might be related to changes in the charging experience, or an adjustment of expectations.

4.3.3 Cross-fleet analysis of factor analysis results

The cross-fleet analysis firstly compares the factors from the individual fleet analysis, and then combines the data of all three fleets and analyses that new data set as a whole.

Overall, the factors are similar across the three fleets, and a good fit to the FAST framework with the latent factors observed from the factor analysis closely linked to the statements in relevant categories from FAST. This confirms the hypothesis that the FAST framework was suitable for the application to the fleets considered in this study, and that the responses from the drivers are mostly in line with the correlation between statements, based on the literature to influence the factors identified, and which are consistent across the fleets.

The main difference for the factor: "Impact of electrification on work tasks" was that Royal Mail drivers initially did not observe difficulties with EV charging in respect to their ability to fulfil their tasks. By iteration two, this has become an issue for all vehicle fleets as EV numbers increased while home, public, and depot-based CPs did not keep up.

Similarly, for iteration one, the statement: "The fact that the electric vehicle can be charged overnight saves working time, as it avoids fuel station trips" (PE3) is correlated to the factor benefits to the organisation (Centrica) and driving experience (Uber). In the second iteration, the statement no longer relates to drivers' opinion on benefits or driving experience, meaning this is no longer seen as a major benefit by drivers.

Having considered the fleets individually, next the fleets have been combined for analysis. For this purpose, the data from drivers of the three fleets have been merged utilising the statements that were common across the three fleets. These statements are shown in Table 39. The corresponding total number of observations is 2,572. Respondents are split in two different ways: EV driver vs non-EV driver, and those who recommend EVs vs those who do not recommend them to colleagues, with the analysis presented below.

Table 39 – Common or equivalent statements across all three fleets (Centrica, Uber and Royal Mail)

FAST Framework	Item	Statement
Management involvement and training	MI1	Our shift to electric vehicles is supported by sufficient information and training provided by our organisation
	MI2	Our managers are implementing strategies and technologies to ensure that the switch to electric vehicles has minimal impact on our tasks
Electric vehicle performance	PE1	Driving an electric vehicle is more pleasant as it is less noisy than a conventional vehicle
	PE2	The acceleration performance of the electric vehicles is very good

FAST Framework	Item	Statement
Effort related to EV adoption	EA1	The limited range of electric vehicles makes/ would make it more difficult to fulfil my daily work tasks
	EA2	Long charging durations for electric vehicles are very impractical
	EA3	The limited availability of charging facilities at and around my home makes it more problematic to use an electric vehicle than a conventional vehicle for the fulfilment of my daily work tasks
Attitudes/emotions & social influence	AI1	I am interested in electric vehicles
	AI2	I think electric vehicles would be beneficial to the environment in the long term
	AI3	I think that electric vehicles would eventually result in cost savings in my industry
	AI4	I think that electric vehicles are generally cool and pleasant to drive
	AI5	I think that electric vehicles are only a temporary phenomenon
	AI6	The range of electric vehicles is sufficient for most daily trips
	AI9	Companies who have electric vehicles have good public image
	AI10	Companies within my industry are considering electric vehicles
	AI11	Electric vehicles are viewed favourably within my industry

The generated factor loadings are illustrated in Table 52 (EV drivers) and Table 53 (non-EV drivers) of Appendix 9.4. The same five factors analysed for each fleet above are identified: 'Benefits of EV to the organisation', 'Compliance to external expectations', 'Impact of electrification on work tasks', 'Considerations of drivers' perspective', and 'Opinion on driving experience'.

The most important finding from this analysis is that, for both EV and non-EV drivers, the factors of iteration one and iteration two contain almost the same statements with very similar factor loadings. This indicates that for both EV drivers and non-EV drivers the same set of statements are relevant, and that these have remained mostly unchanged between the first and second iterations of the questionnaire. They therefore indicate clear relationships between statements and variables which can be used when designing further interventions and monitoring impact.

Related to this, the only change in the number of statements manifesting the latent factors can be noticed from the EV drivers in iteration two where the statement: "the range of electric vehicles is sufficient for most daily trips" (AI6) loads on the factor: "impact of electrification on work tasks", as has been observed in the factor analysis results of Centrica. The semantically positive statement AI6 and the negative statements EA1, EA2 and EA3 have a different direction and, therefore, opposite loading signs. One interesting difference is for statements related to availability of charging infrastructure (EA3). For EV drivers, the loading increases between iteration one and iteration two indicating growing concern with access to charging, but for non-EV drivers over the same time interval this is decreasing – suggesting that those who do not have to charge a vehicle themselves have the impression that this is getting easier. In both cases it continues to be the third ranked statement related to the impact on work tasks, with range and charging time having a higher loading than availability of charge points. This could indicate a gap between expectations and reality.

Key insights:

- Availability of charging points was loading for the factor: "impact of electrification on work tasks" for Centrica and Uber already in the first iteration, but for all three fleets after the second iteration.
- The statement "the fact that the electric vehicle can be charged overnight saves working time" is no longer an area of concern in the second iteration, where this was present to

explain the variance of benefits to the organisation (Centrica) and driving experience (Uber) in iteration 1.

- When combining the data for all fleets, and separating them into EV drivers and non-EV drivers, the same five factors analysed for each fleet above are identified: 'Benefits of EV to the organisation', 'Compliance to external expectations', 'Impact of electrification on work tasks', 'Considerations of drivers' perspective', and 'Opinion on driving experience'. No significant changes can be observed from the data for each fleet individually.
- EV drivers are increasingly concerned with charging access, while non-EV drivers have the perception that access is becoming easier.

4.3.4 Effect of influence from colleagues

Following the analysis of the combined fleet for EV drivers and non-EV drivers, the population is split in two depending on their overall recommendation to others. The project considered similar statements on whether they would recommend EVs to other drivers (for Centrica and Uber) or their stated preference driving an EV versus a conventional vehicle (in the case of Royal Mail). While these are not fully equivalent statements, they are considered as representing an overall attitude towards EVs based on experience of both EVs and previously ICEVs. Figure 106, Figure 107 and Figure 108 on the following pages show the responses to the equivalent statements (as listed in Table 39).

The figures show a marked difference responding to the factor: "impact of electrification on work tasks" in which drivers who themselves do not recommend an EV to others mostly or entirely agree with the statements pointing out the (experienced) drawbacks of driving an EV: limited availability of charging facilities (60% mostly or entirely agree – EA3), long charging duration (~50% mostly or entirely agree – EA2) and limited battery range (40% mostly or entirely agree – EA1). Those who do recommend EVs to others have far more positive views/experiences on these themes, though a significant number still agree that these are obstacles, particularly EA3 with 40% of EV drivers who mostly or entirely agree, while for EA1 and EA2, these numbers decrease respectively to 20% and 30%.

Individuals who do not recommend EVs also show some doubts on the EV performance: a large percentage disagree with the fact that the EV is more pleasant because they are less noisy (PE1), have a good acceleration (PE2) or are 'cool' (AI4) (~25% somewhat to entirely disagree), which is significantly different from drivers recommending the EV, for which the level of agreement is nearly 100%. This may be related to different preferences, perhaps related to the specifics of the job. Different types of vehicles could be considered as part of the fleet if alternative models would be better received by those not keen on the current model.

A large percentage of EV drivers who do not recommend an EV perceive that the shift to EVs is not supported by sufficient information and training provided by their organisation (~30% mostly or entirely disagree – MI1) and by adequate strategy and technologies to minimise the impact (~25% mostly or entirely disagree – MI2). Additionally, drivers not recommending EVs are sceptical about the benefits on the environment (~30% somewhat to entirely disagree – AI2) and the potential cost-saving for the industry (~25% somewhat to entirely disagree – AI3).

This difference in responses to these key factors suggests broad obstacles for those who are currently not recommending EVs to others based on their current experience. Early positive experiences and training for transition therefore remains a key aspect of fleet electrification for employees.

Figure 106 – EV drivers not recommending EVs

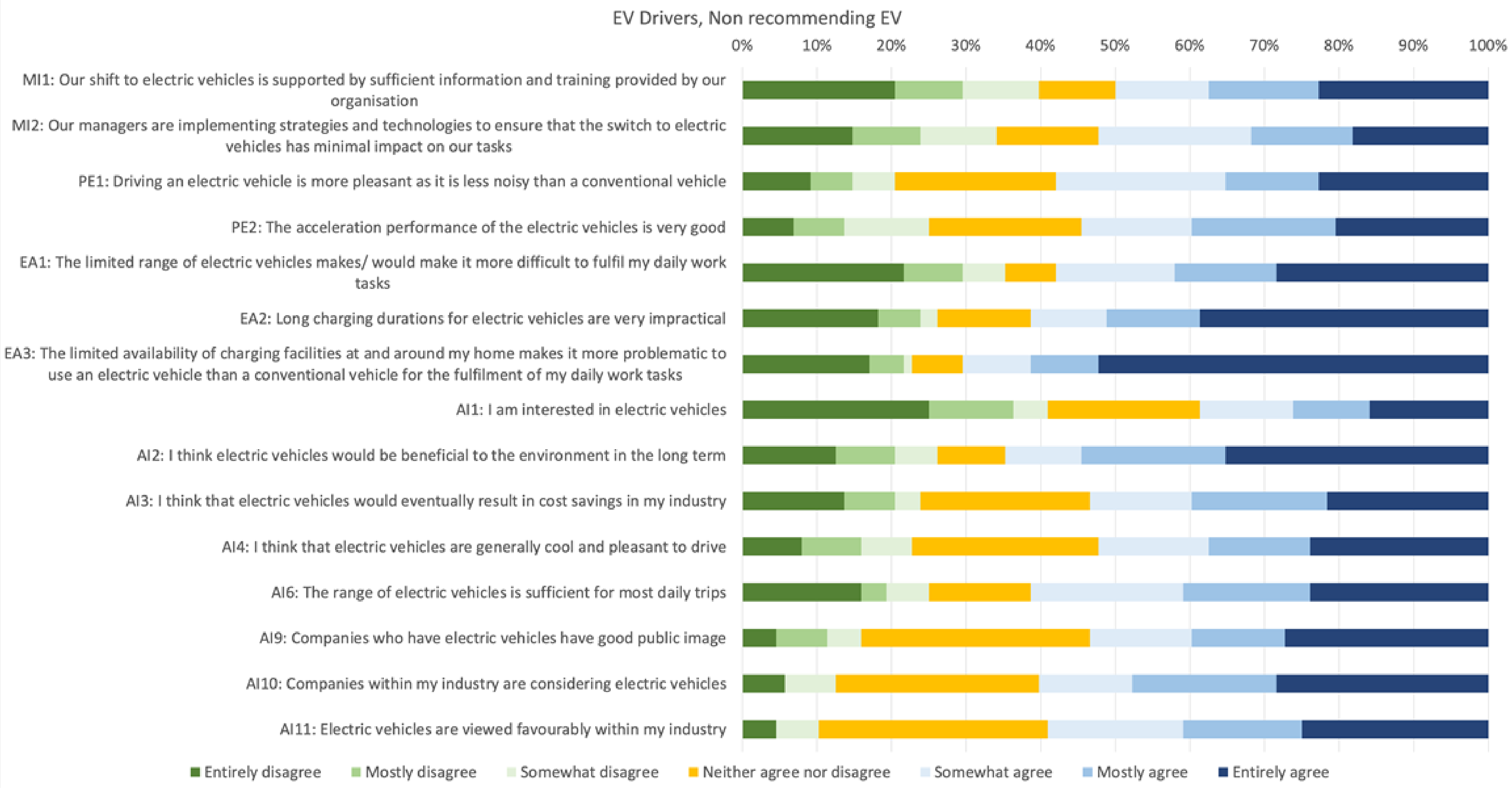


Figure 107 – EV Drivers unsure about recommending EVs

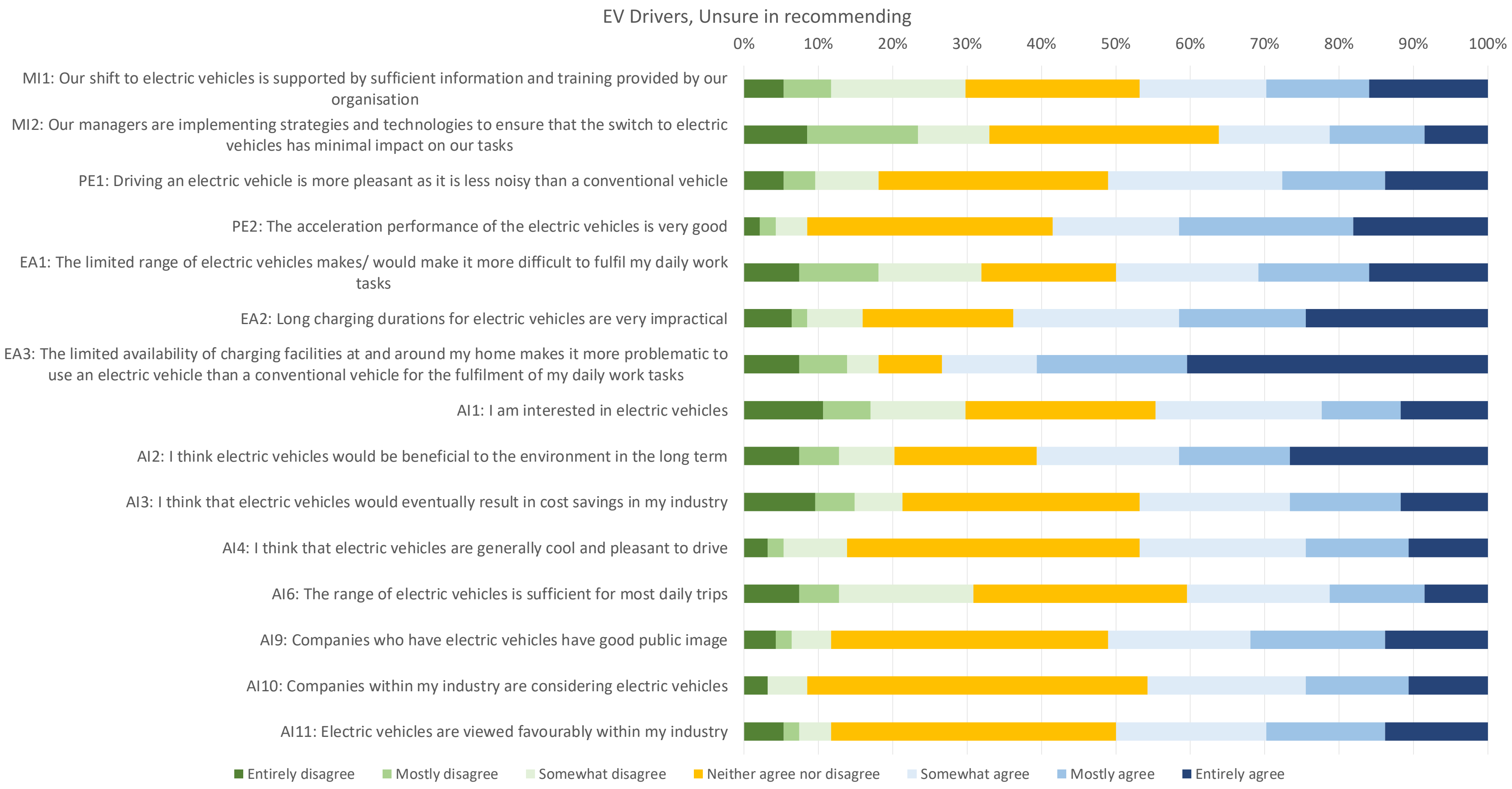
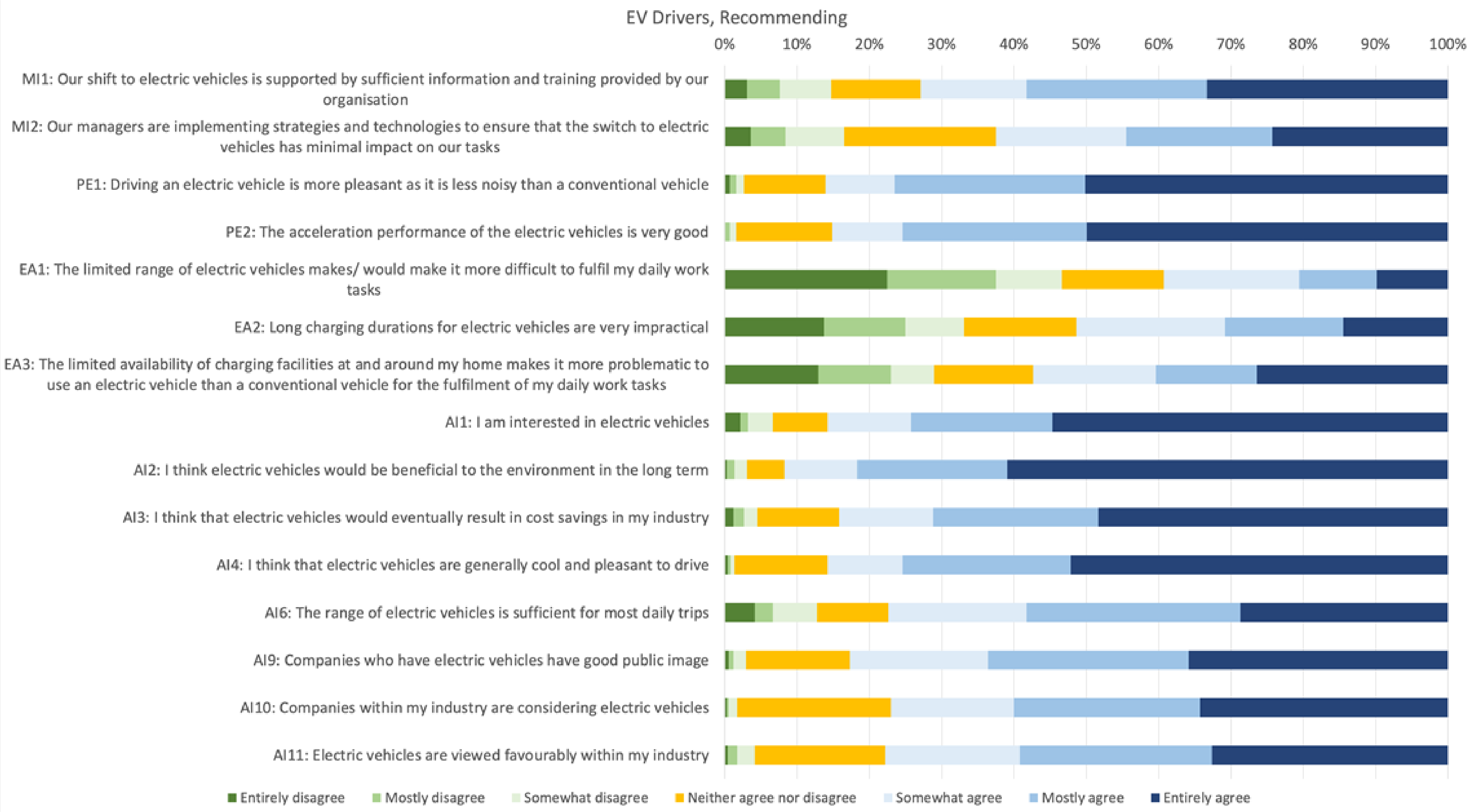


Figure 108 – EV drivers recommending EVs



It is also important to note that across the statements of the EV drivers who are unsure about recommending an EV, the percentage of people responding “neither agree nor disagree” is very high for the statements related to the latent factor: “compliance to external expectations”, which show that these drivers do not have a clear idea or they are neutral about strategies of other companies within their industry.

Key insights:

- Those EV drivers who said they did not recommend EVs have a markedly different response to statements relating to the factor “impact of electrification on work tasks”, highlighting their obstacles related to access to charging, charging duration, and range. Those who would recommend EVs to others feel much more positively about these areas and are less concerned about the impact on their tasks.
- Respondents who do not recommend EVs also show doubts on EV performance, while there is a greater than 95% satisfaction among those who would recommend them. This means individual preferences can diverge even when informed by experience from the same vehicles and should be considered when selecting a vehicle or providing options for different models.
- Those not recommending EVs often do not feel that the transition is supported by management, and do not recognise environmental and cost-saving benefits to the organisation as much.
- The fact that those who are not happy with their EV have broad concerns over a range of technical, organisational, economic, and environmental aspects means there is not a single area that needs to be improved to ‘get them on board’. The particular concerns of those drivers could be explored further to identify how they could be addressed.

4.3.5 Conclusions and Further Analysis

The results for the three fleets demonstrate how the factor loadings compare between iteration one and iteration two, and between the various types of fleets, as well as for the combined data between EV drivers and non-EV drivers. The following key insights have been extracted from the study and the completed factor analysis:

- The three fleets, Centrica, Uber and Royal Mail, have similar factor loadings, though with some notable differences. Overall, this suggests lessons learned can be translated between fleets, given that the variation in responses for the examined statements can be linked to the same factors.
- Some small changes can be observed on the influence of charging, possibly linked to new habits or better understanding. For Royal Mail there is a clear increase in difficulty with access to charging points which has become a key area of concern by iteration two.
- The benefits related to both cost and environment seem to be clear to the survey respondents.
- Drivers are aware of the interests of both private and public stakeholders on the EV transition and recognise the impact of these views on the expectations for their organisations, and this appears to be improving (notably for Centrica)
- EV drivers positively rate their vehicle and driving experience. The driving experience is shaped mostly by noise, acceleration, and how ‘cool’ the EV is perceived. There are few changes in between iterations, so opinions on these topics do not significantly shift over time.

- The main difference between EV and non-EV drivers between the two iterations is that for EV drivers there is a growing concern with access to charging. For non-EV drivers over the same time interval this concern is decreasing.
- Those EV drivers who said they do not recommend an EV have a clearly different response to barriers, advantages and management support compared to those who would recommend EVs to colleagues. Those who are not happy with their EV have broad concerns over a range of technical, organisational, economic, and environmental aspects which means there is not a single area to improve to change their views.

Based on the results of the factor analysis the following opportunities for further analysis have been identified:

- The two iterations of the questionnaire were conducted to explore how views have changed over time. D7 will further explore how interventions from the companies, Optimise Prime team, or external factors have impacted driver experiences.
- Specific interventions could be designed to test their effectiveness in subsequent iterations of the model, based on the factors in this study. It should be stressed that the study itself can be seen as an intervention too, as the questionnaires and interviews could have been a trigger for staff to discuss the topic of EVs (and other topics related to sustainability) and share experiences, leading to information sharing and helping to resolve common misconceptions.
- Discussions could be facilitated between EV advocates and those who are not happy with their EV to extract insights in how individual circumstances and preferences shape their views, especially since these are markedly different across a wide range of themes. It is also possible be that differences are linked to a specific local context, and therefore that other external factors influence these views which have not been captured by the study.

4.4 Complementary behavioural analysis – Novuna Customers

4.4.1 Context

In order to analyse whether the results from Royal Mail, Centrica and Uber are applicable to the other fleets, the Optimise Prime behavioural studies were extended to drivers of three Novuna Vehicle Solutions' customers. These were a convenience store company, a veterinary care group, and a freight company. These companies are at a relatively early stage of electrification as part of Novuna's objective to operate a fully decarbonised fleet by 2030. The questionnaires took a similar form to those of the other partners and the response rates are shown in Table 40.

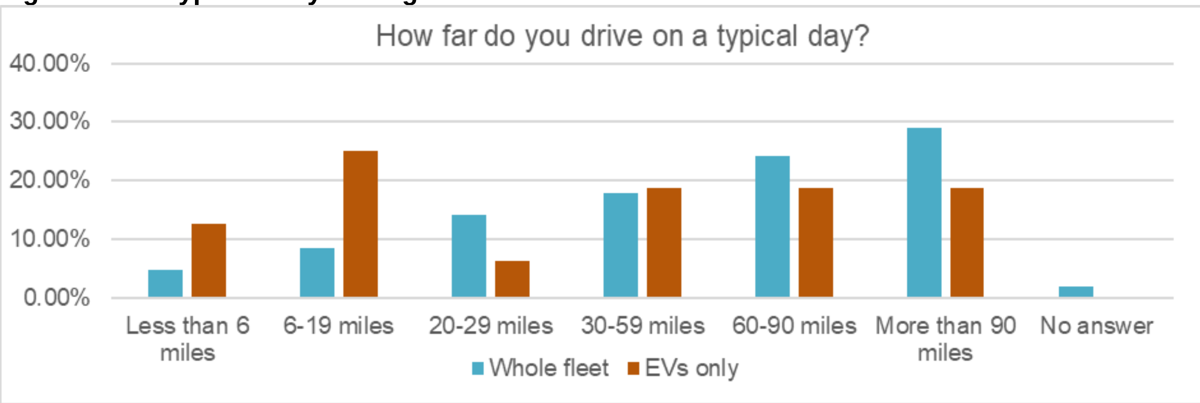
Table 40 – Novuna questionnaire responses received

Customer	Response rate (as a % of the company's drivers	Percentage EV drivers in responses
Convenience store company	21.79%	9.80%
Veterinary care group	9.06%	17.86%
Freight company	5.68%	23.08%
Combined fleet	**10.49%**	**15.24%**

Due to the relatively small samples in this survey, the results of the Novuna customers are grouped together in this analysis. The survey results include drivers who drive cars (68%), Nevans (14%) and heavy goods vehicles (1%). 17% of respondents did not answer the vehicle type question, potentially because they drive multiple vehicle types. The EV drivers predominantly drove cars.

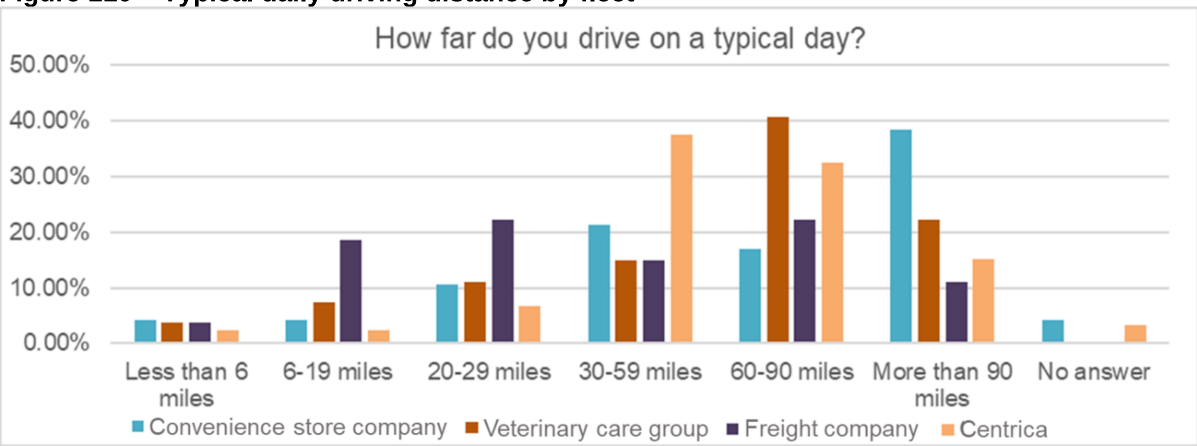
More than half of drivers (53%) said that they drive at least 60 miles on a typical day; nearly 29% drive over 90 miles in a day which makes this the largest group; 27% of drivers typically travel less than 30 miles (Figure 109).

Figure 109 – Typical daily driving distance – EV vs whole fleet



EV drivers appeared to drive less than average miles with more shorter trips and fewer longer trips, although due to the small number of EV drivers in the sample further research is required to confirm to what extent their trips are different from average

Figure 110 – Typical daily driving distance by fleet



As shown in Figure 110, Novuna customer drivers typically drive longer distances than Centrica's (29% vs 15%), but at the same time there are more Novuna customer drivers who do short trips (27% less than 30 miles vs 12%). For Centrica, the 30-59 miles range was the most common answer (38%). Overall, the use of the vehicles included in this study is similar to Centrica (rather than Uber or Royal Mail), but with a different distribution of journey lengths and the use of cars rather than vans.

4.4.2 Factor analysis of the Novuna fleets

The investigation of the FAST construct for Novuna fleets was performed using Exploratory Factor Analysis on 30 statements, which are the same as those presented to Centrica's drivers in the second iteration questionnaire. Due to the smaller number of responses the Novuna customers were considered as a single fleet, for the purpose of factor analysis, and it should be noted that the majority of respondents (89 out of 105) were not EV drivers.

The full results of the factor analysis can be found in Appendix 9.5. Key insights from the factor analysis of the Novuna customer responses include:

- Novuna customer drivers believe that information is communicated efficiently by their organisations and are consulted regarding the switch to EVs
- Drivers are conscious that the transition to EVs is targeted by government and other businesses, and that customers might also expect their business to switch to EVs
- EV acceleration and lack of noise lead to positive perception of EVs
- Amongst the population of mostly non-EV drivers, there is particular concern about limited availability of charging facilities, limited range and long charging durations.
- The company's good public image, the advantage given by the low energy cost, the benefit to the environment in the long term are perceived as the most important benefits of EVs to the organisation.

The small sample did not allow the project to conduct a reliable EFA separately for the EV drivers. Therefore, a frequency analysis was performed to understand if there are potentially interesting differences in response between the two groups. The main findings, based on a small sample, were:

- A higher percentage of EV drivers believe that the performance of EVs are better than conventional vehicles, especially with regards to noise (more than 40% of EV drivers mostly or entirely agree) and acceleration (more than 80% of EV drivers mostly or entirely agree).
- 40% of EV drivers entirely disagree with the question about forgetting to plug-in and almost 30% entirely disagree with the fact that the limited range might affect the daily work task. Only 15% mostly or entirely agree that smart charging is risky.

4.4.3 Insights

Based on the analysis of the initial Novuna survey results the project concludes:

The results of the factor analysis are similar to those obtained for Centrica, Uber and Royal Mail fleets

This confirms that the results and recommendations can be generalised.

The Novuna customer survey has not produced sufficient data to make conclusive comments about the difference between EV and non-EV drivers

However, analysis suggests that there are potentially interesting insights that could be obtained around evaluation of how the vehicle, charging facilities and the wider range of distances driven impacts on work tasks, and how views on these matters may evolve as a result of exposure to EVs.

With the varied distribution of typical driving distances within each customer fleet, there are notable differences between the fleets.

It will be important to study further the link between work tasks (and related expected journey lengths) and positive attitudes from the drivers. The project plans to expand the Novuna customer questionnaires with a further round of surveys in order to capture views from a larger sample of drivers.

4.5 Next steps

Additional data collection from other fleets, including additional Novuna customers, is planned. This is expected to provide a wider ranging view on opinions and the likely speed of transition of fleets of different characteristics.

Updated results of the behavioural analysis will be presented in Deliverable D7.

5 Early Learnings on Profiled Connections

5.1 Background to profiled connections

Profiled connections are one of the core elements of the depot charging innovative solution. This new connection type is intended to enable depot-based fleets to connect to the network cheaper and faster, by optimising network assets utilisation to allow more EVs to connect to the distribution network before needing to reinforce network assets. This is achieved by matching connection requests with expected demand throughout the day. With a profiled connection, customers with control over their load could use additional capacity at times when it is not required by other customers, while using less when the network is constrained.

In Ofgem's Access and Forward-Looking Charges Significant Code Review, which is currently awaiting decision, 'time-profiled access rights' have been suggested as a means to enable a more efficient use and development of system capacity. A profiled connection is an example of this type of connection and could provide a means for depot-based fleets to switch to electric more quickly, while minimising their connection cost by reducing, avoiding or deferring upstream network reinforcement compared with the traditional connection charging methodology. Avoiding or deferring such reinforcements through a more efficient use of existing infrastructure will also save costs for all network customers.

Optimise Prime has implemented the ability to set charging at Royal Mail sites to follow (as far as possible) a profiled connection, and has introduced systems in UK Power Networks' estate to allow the assessment of profiled connections, the monitoring of profiled connections and alerting for when breaches occur.

The profiled connections trials are in progress and are looking at the technical capability of the Royal Mail sites to adhere to profiles that have been set for them based on analysis of historic electricity use and charging requirements. This section presents an overview of the learnings developed so far from the trial activity.

5.2 Profiled connection methodology

5.2.1 How profiled connections work

For the purposes of Optimise Prime, a profiled connection agreement is defined for a given supply at a given site as follows:

A connection agreement where the applicable maximum demand limit (in kVA) varies according to the time of day and the season, up to 48 half-hourly time slots per day, with adherence to the profile actively managed through behind-the-meter smart systems and monitored by the DNO.

An illustration of the maximum load profile for a winter's day at a site with a profiled connection agreement is shown in Figure 111. It is envisaged that a different profile could apply in different seasons.

Figure 111 – Illustrative standard and profiled connection agreement demand load limit

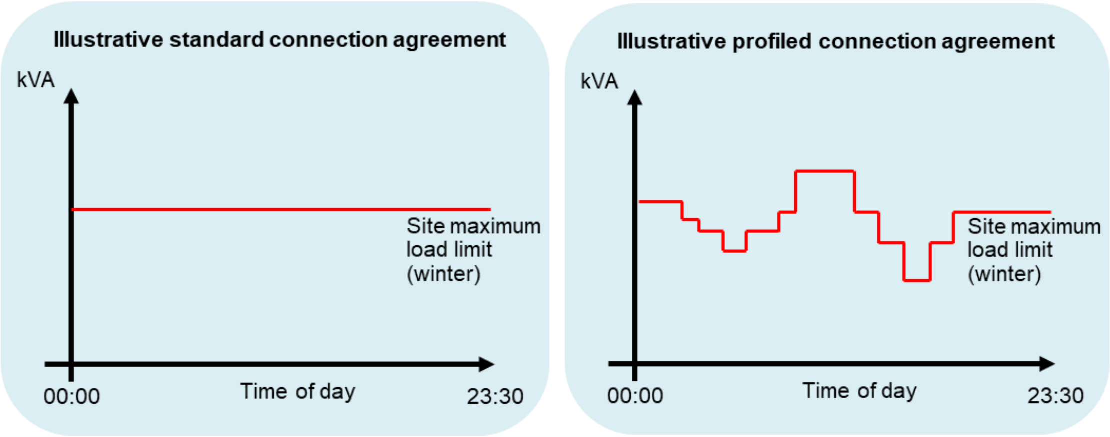
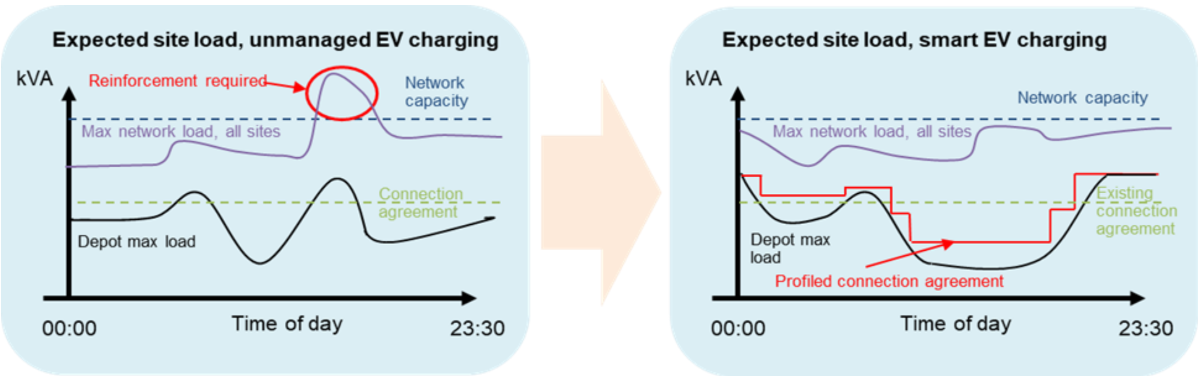


Figure 112 shows how a profiled connection can help network reinforcement to be avoided. On the left-hand chart, the expected maximum depot load, resulting from a larger EV fleet, exceeds the depot's connection agreement (dashed green line). The resulting load on the network (in purple) exceeds the existing network capacity (dashed line in blue). The vehicle charging schedule is then adjusted to charge over a longer period, into the night, rather than when than as soon as vehicles return to the depot, at the end of their operations (during the day). This shift in EV charging changes the timing of depot electricity consumption from the pattern shown by the black curve, on the left-hand chart, to that of the black curve, on the right-hand chart. This has the effect of reducing the load on the network at peak time. This enables the EV charging load to be accommodated within the existing network capacity rather than reinforcing the network (on the right-hand chart, the purple curve is now below the blue dotted line throughout the day).

Figure 112 – Site load comparison, without a profiled connection (unmanaged) and with a profiled connection (smart EV charging)



Adopting a profiled connection (in red on the right-hand chart), rather than a standard connection agreement (in dashed green), enables the depot operator to increase the depot load above the existing connection agreement level, at certain times of day, at no additional cost, provided that the depot load is minimised at the times of day when the shared network assets are most constrained. This enables the depot operator to accommodate a larger fleet at the depot than would be possible just by smart charging to fit the EV load within the existing connection agreement capacity.

Further information on the profiled connection methodology was published in Deliverable D2, section 3.2.1.

5.2.2 Requirements for implementing profiled connections

To plan, enact and conform to a profiled connection agreement requires specific technical capabilities to be in place on both the depot operator's side of the meter and on the DNO side of the meter. A number of elements have been put in place and are being practically tested as part of the Optimise Prime trials, including:

DNO

- **Connection planning** – As described in Deliverable D2 (3.2.3), UK Power Networks have adapted their planning tools to accept connection applications that vary at up to 48 half-hourly periods.
- **Active network and site monitoring –** for the DNO to actively monitor and manage any risk related to profiled connections, a form of monitoring is needed. In the Optimise Prime trials, UK Power Networks installed monitoring systems either at substations or at customer premises, as described in Deliverable D3 (3.4.1). This system integrates with UK Power Networks' Active Network Management system to generate alerts when profiles are breached.

Additionally, commercial implementations of Profiled Connections may require failsafe systems to protect the integrity of the network in the event of a breach. Such a system was not required, in order to carry out the trials, because all sites are operating within their existing ASC. The trials team are considering potential methods, both technical and commercial to achieve this when the capability is rolled out.

Depot Operator

The depot operator must be capable of defining the required profile and maintaining load within that profile, which may include the following:

- Collecting historical site data for the location and modelling depot maximum power requirements for various scenarios of fleet electrification in order to plan a profile. A Site Planning Tool has been developed by Optimise Prime to help fleet managers quantify their connection requirements before applying for EV connections, highlighting the required data and allowing the customer to simulate different scenarios. It is planned to migrate this tool to the UK Power Networks website at the end of the project.
- Smart charging vehicles within the profile – this could potentially be achieved by a dynamic system, taking into account real-time load, as is being tested in Optimise Prime, or by setting load limits within each CP

The following section details the outcomes from the initial rounds of profiled connection trials and the findings to date.

5.3 Preliminary findings from trial of profiled connections

5.3.1 Profiled connections trials

A number of profiled connection trials have been conducted at Royal Mail sites. These were trials of pseudo profiled connections, imposed artificially at sites, where there is no actual constraint on ASC headroom, in order to ensure the trials do not present a risk to network integrity or Royal Mail's operations, and due to the fact that the CPs were put in place before Profiled Connections could be offered. Throughout the trials, drivers were not explicitly informed of the trial activity (though the management team were informed) and were not expected to make changes to their routine to accommodate the trials.

The first trial, carried out in July 2021 was held to test the project's ability to influence charging patterns through a profiled connection. The outcome of this was documented in Deliverable 4, section 3.6.4 and demonstrated the ability to shift charging patterns.

The second trial, in September and October 2021 involved seven Royal Mail delivery offices at Camden, Islington, Dartford, Premier Park, Whitechapel and Victoria. These delivery offices, while all in London, represent a range of different sizes and different vehicle-CP ratios.

A third test started in January 2022, implementing methodology changes based on learnings from the previous iteration.

The trials have provided valuable insights into the real operational issues to be considered in managing an EV depot under a profiled connection agreement and the initial learnings from the trials are detailed in the following sections.

5.3.2 Creating the profiled connection – September-October trial

The key initial step when requesting, and offering, a profiled connection is to create an appropriate profile. For the September/October 2021 trials, vehicle schedules, obtained from telematics, including journey start and end times, distances travelled and proportion of EVs running each schedule, were used to predict the EV load that would need to be managed by the profile. A daily profile, which gave the same capacity on each day of the week was created.

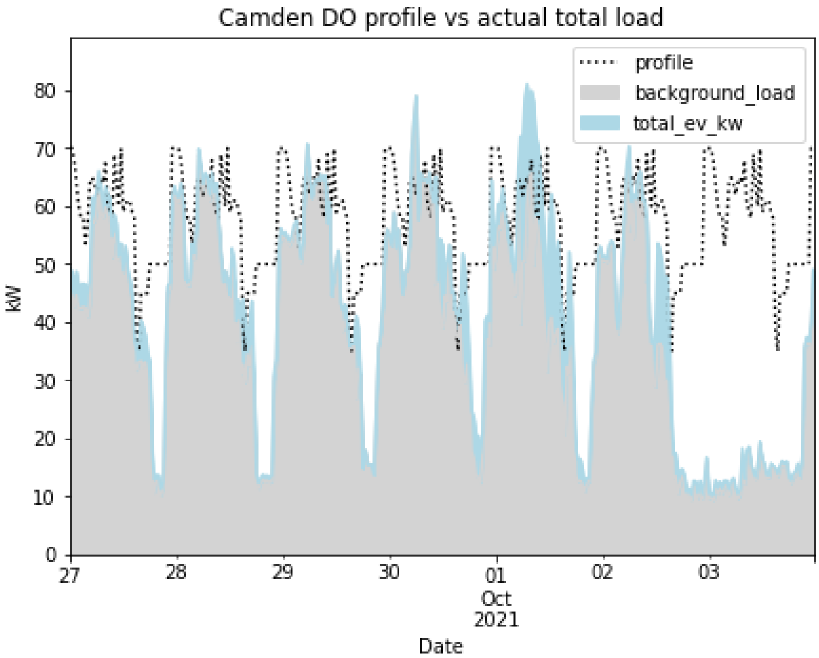
Modelling was used to generate the load profile for each of the depots, taking into account both historical background demand and the calculated EV load.

5.3.3 Outcome of the September – October trials

The outcome of the trial in September-October found that while depots were able to maintain the profile the majority of the time, all depots experienced some level of breach.

For example, at Camden, the algorithm suggested a more granular profile, as shown by the dotted line in Figure 113, which was breached 17% of the time, with a maximum breach of 28% higher than the profile (~15 kW breach). This was one of the smaller depots in the trial with 12 EVs using six sockets across three CPs.

Figure 113 – Profiled connection and power use at Camden Delivery Office

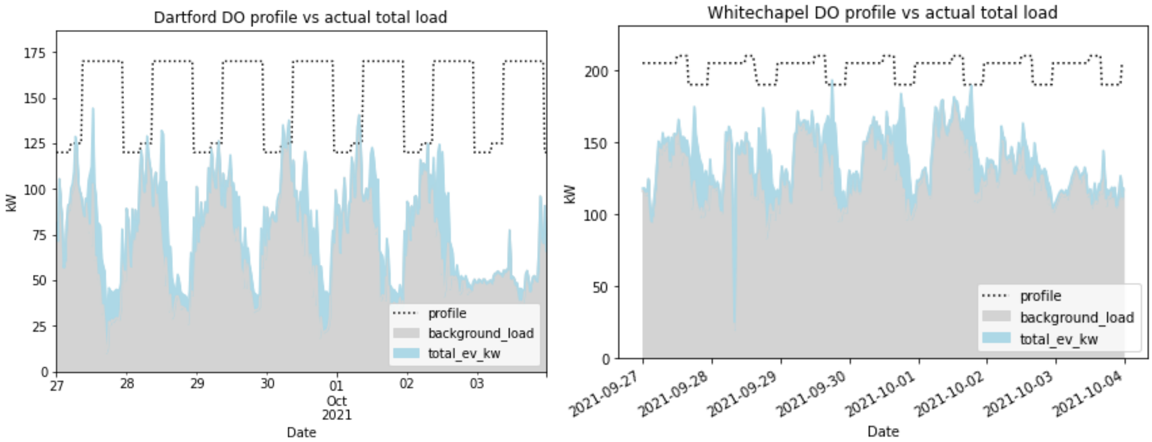


While Camden represented the most extreme example of a profile breach, similar effects were seen across a number of other depots.

At Dartford and Whitechapel Delivery Offices (Figure 114) which are larger and have more vehicles, the profiled connection produced was less granular, and also afforded a larger ‘buffer’, when compared with Camden, because of larger historic variations in background load.

Importantly, at most times of day, the EV load does not need to be controlled due to the generous profile and the lower ratio of EV load compared with building load. However, there are still times when the profile is breached, driven by spikes in background load.

Figure 114 – Profiled connection and power use at Dartford and Whitechapel Delivery Offices



At small delivery offices, such as Bexleyheath, the controllability of the load was more of a factor. As documented in previous deliverables, in order to avoid disrupting operations, the system implemented at Royal Mail delivery offices will always deliver a minimum 6A charge (~1.4 kW) to vehicles, and when an unidentified vehicle plugs in charge is not controlled. The large amount of uncontrollable load is likely to be the cause of the spikes seen in the results in Figure 115.

Figure 115 – Profiled connection and power use at Bexleyheath Delivery Office

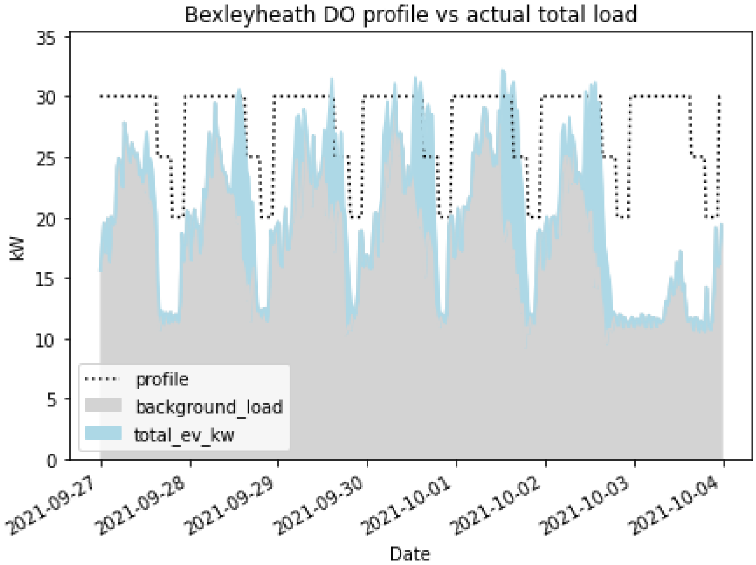


Table 41 shows the results of the profiled connection trials by depot.

Table 41 – Profiled Connections results September and October

Depot name	Breach rate (% time breached	Max Breach (% profile breached by)	Profile 'headroom' to average load
Bexleyheath	7%	24%	8 kW
Camden	17%	28%	18 kW
Dartford	3%	12%	71 kW
Islington	14%	72%	11 kW
Premier Park	2%	20%	45 kW
Whitechapel	0.3%	2%	62 kW
Victoria*	0%	0%	63 kW

*Victoria was discounted because of a fault in the building load readings.

In summary, several factors appear to have contributed to these breaches, including:

- Vehicle schedules do not relate to charging times – for example, at Camden, it is clear that minimal charging takes place earlier in the week, with more EVs plugged in as the week progresses. The schedules derived from the telematics assumed that all EVs would be plugged in when they returned to the depots. This is unlikely to happen in reality, especially in depots where there are multiple vehicles per CP.
- Background load being very variable and large in volume, in proportion to the EV load that can be controlled. If the volume of the controllable EV load is less than potential the variation in building load, controlling EVs cannot ensure compliance with a profile.
- Potentially there have been changes at the sites between the base data being captured and the time of the trial (e.g. additional EVs, EVs that that cannot be managed or changes to working practices altering the background load profile).

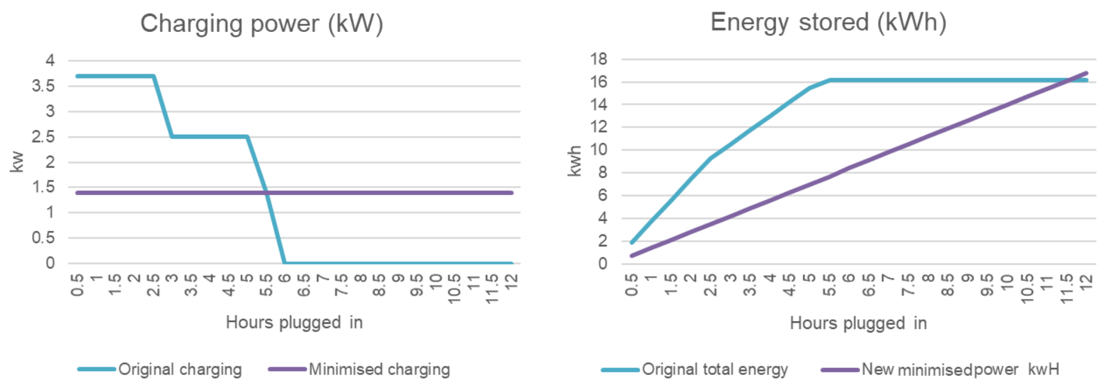
5.3.4 Revising the profiled connection methodology

Based on the results of this first round of profiled connections it was decided that it was necessary to revise the profiles, with several key objectives:

- Protection for the network against profile breaches while still aiming to minimise EV load
- Ensuring all EVs had sufficient charge
- Control of profile granularity (i.e. same granularity for all sites)
- Account for site changes (i.e. new EVs arriving at/leaving depots).

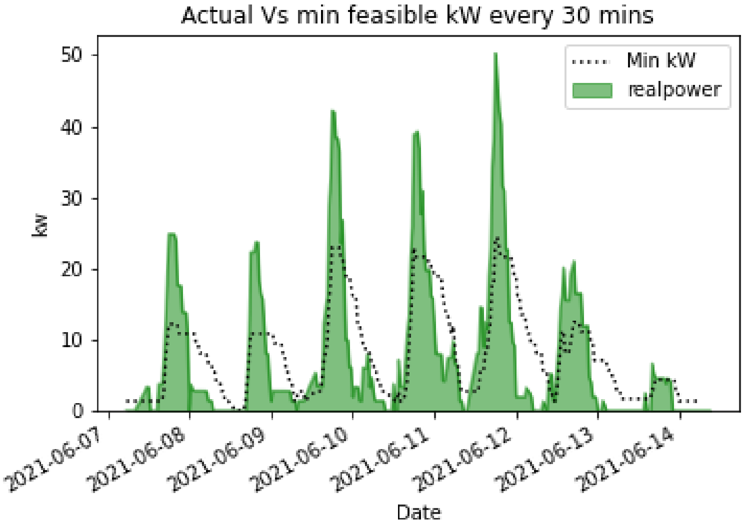
The key changes in this iteration of the methodology were to utilise actual historic EV charging data, rather than estimating charging times based on vehicle movements and to vary the profile specific to each day of the week. Figure 116 gives an overview of how, in principle, the charging profile of a vehicle could be altered to achieve the same charge delivered to the vehicle, at the end of the night, with a lower maximum charge power (the purple lines) compared to unmanaged charging (the blue lines). This minimum charge level is needed to establish an expected minimum EV charging power possible at a depot.

Figure 116 – Unmanaged and minimised charge power (left graph) and resulting battery state of charge (right graph)



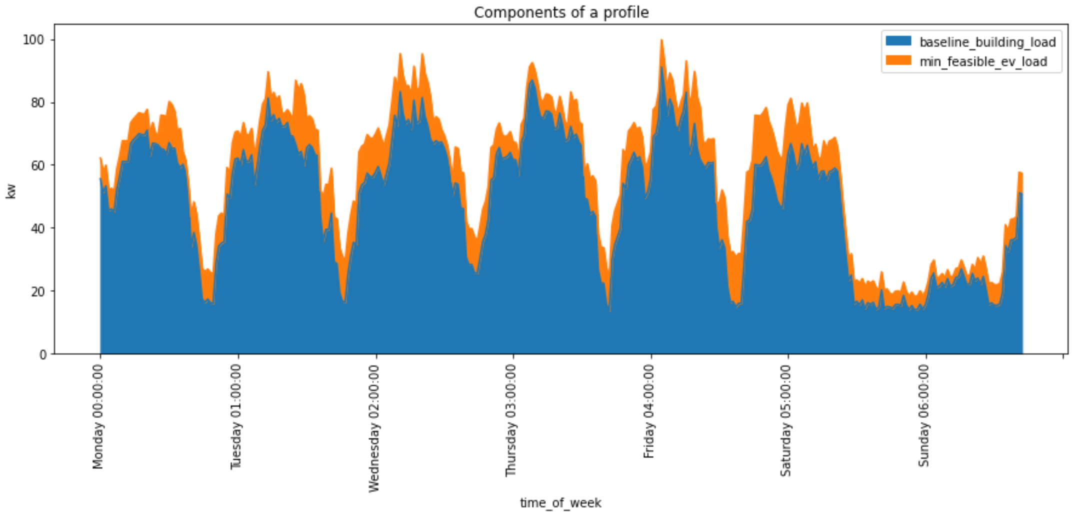
When this is applied across all EVs in one depot over a week (using data from the first month of trials), the modelled minimum EV power (black dotted line in Figure 117) can be seen in comparison to the power requirement for unmanaged charging (green). These power values ensure the EVs would have received the total energy they did while using unmanaged charging but at different times.

Figure 117 – Actual vs minimum feasible charging demand



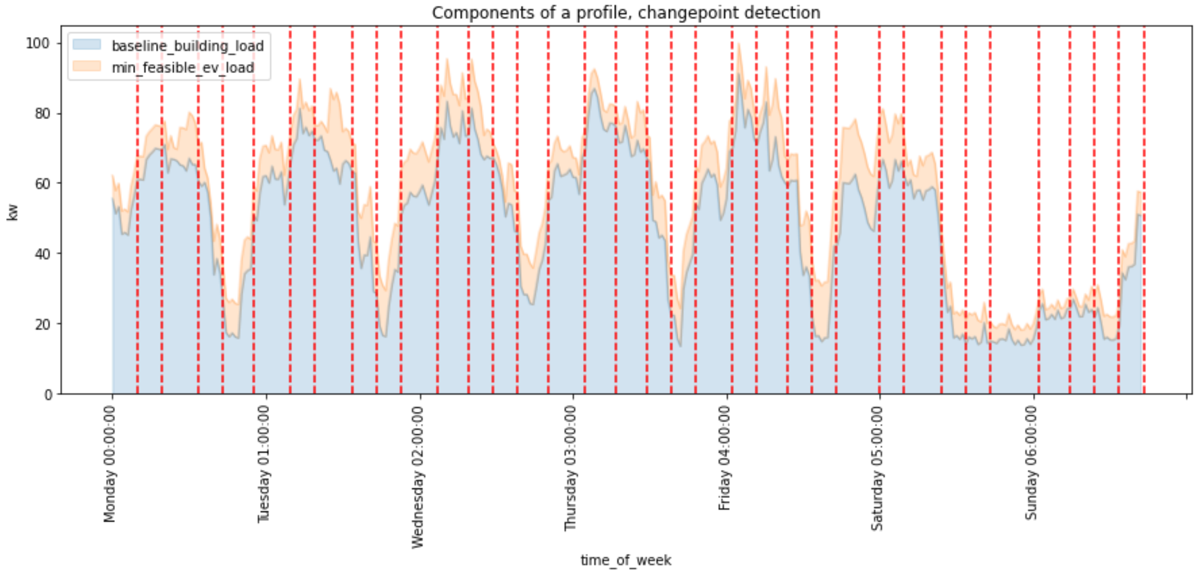
Once the minimised charging pattern of the EVs has been calculated, it can then be layered on top of the background load. A 99-percentile background load was used to account for the highest normally expected load. As shown in Figure 118, this creates a noisy profile that is constantly changing.

Figure 118 – Minimum EV charging demand overlayed onto base load



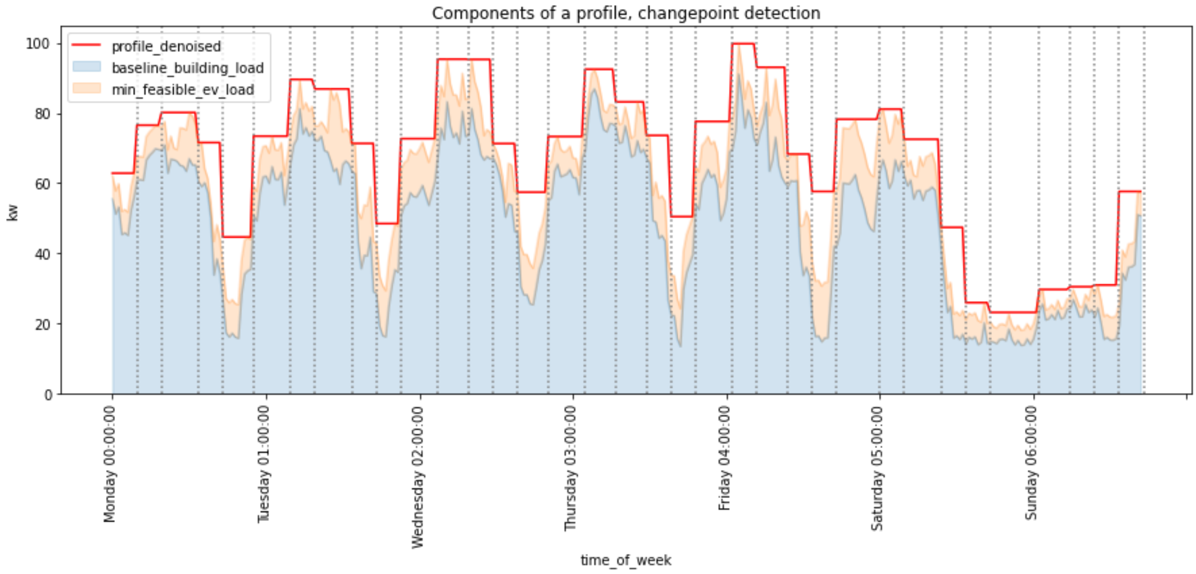
Time series changepoint detection was then used to identify key points in the 'noisy' profile where load alters, as shown by the red dashed lines in Figure 119.

Figure 119 – Detected changepoints in power demand



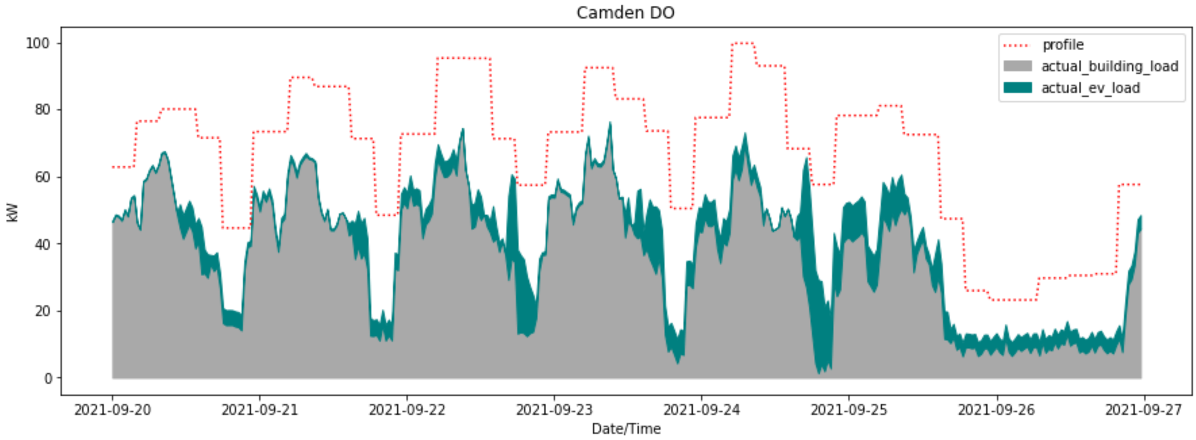
Detecting the changes in power points then allows the automatic setting of a less 'noisy' profile based around the maximum value within each change window. These are aligned with the half-hourly Programme Time Units (PTUs) in order to create a profiled connection, as shown in Figure 120.

Figure 120 – Profiled Connection derived from base and EV charging load data



This technique was applied to the Camden Delivery Office and compared to actual load in a specific week (w/c 25 September 2021). As can be seen in Figure 121, the profiled connection would not have been breached in this week with the new methodology.

Figure 121 – Modelled profiled connection superimposed on Camden Delivery Office actual load



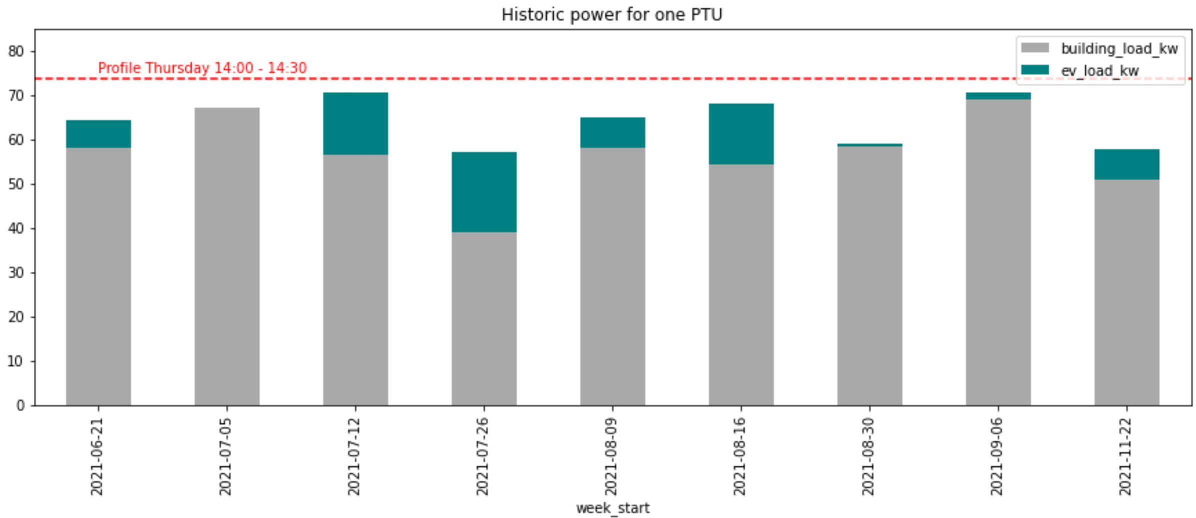
However, the profiled connection would also not result in any shifting of EV demand. In this situation, there is not a large enough EV load, relative to background load volatility, to see the benefit of profiled connections. This is because the buffer that needs to exist to account for changes in background load is greater than the total EV load.

This profiled connection may still be beneficial in giving the DNO better understanding of actual load for planning purposes, but using EVs as an asset class, cannot, in this situation, make a profiled connection a workable solution for the depot.

5.3.5 Variability of load at a specific point in time

To comply with a profiled connection, the profile must account for the largest background load plus the minimum EV load that will fully charge the vehicles in the time available and a small buffer. Figure 122 demonstrates the variability that has been observed for a specific weekly PTU over a series of nine weeks, and the profile that would be created for this period based on these rules (the red dashed line).

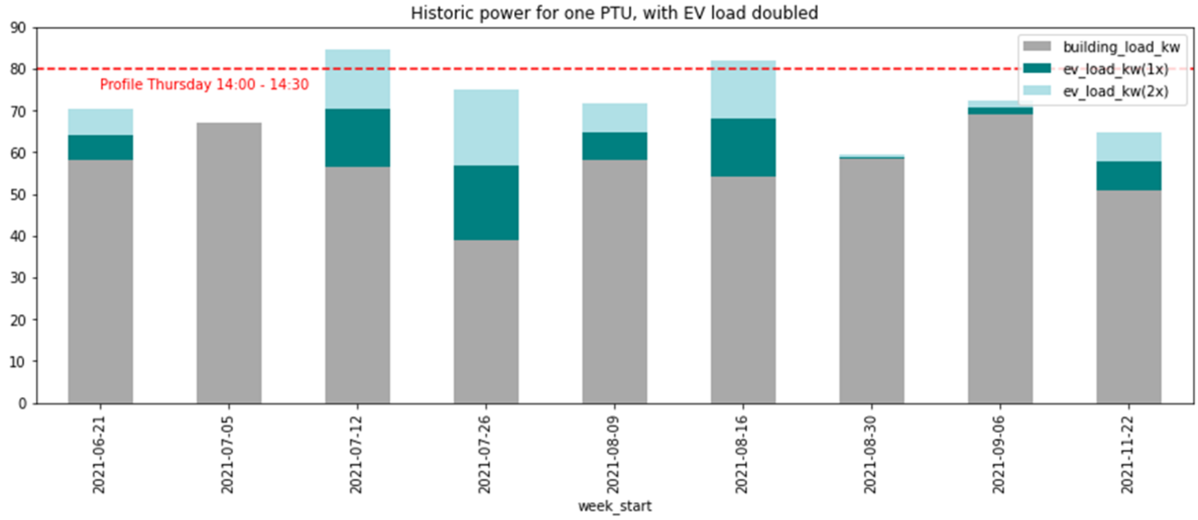
Figure 122 – Variability of Load for one PTU



The main driver for the profile being set at this level is the potential for high background load during this time. In some weeks, such as the week of 26 July, the proportion of EV load is larger, but a profile cannot be set on this alone because the far higher background load seen on 6 September needs to be considered. If the profile was based on 26 July, then five out of nine weeks would breach the profile.

A scenario where the EV load was doubled was the applied. In this case, Figure 123 shows that there would be relatively little increase in the calculated profile. In this example the unmanaged EV load exceeds the profile at certain times, but this could be managed to stay below the profile.

Figure 123 – Variability of load for one PTU, with EV load doubled



Based on the findings from the investigation so far, our current finding is that profiled connections managed by EVs will be feasible if:

EV load > (Max(Background Load) x1.1) – Min(Background Load)

In practice, this means that sites where a profiled connection is suitable are sites where the EV load is larger than the background load variability of Max-Min, plus a small margin (10%) to allow time for the control system to react to changes in background load.

5.3.6 Test of second iteration of profiled connections

Between 20 and 27 January, the project ran a profile using the new methodology to set profiled connections outlined in Section 5.3.4.

The test ran against two delivery offices, Premier Park and Victoria, because these two offices are where the EV load was largest compared to the background load volatility.

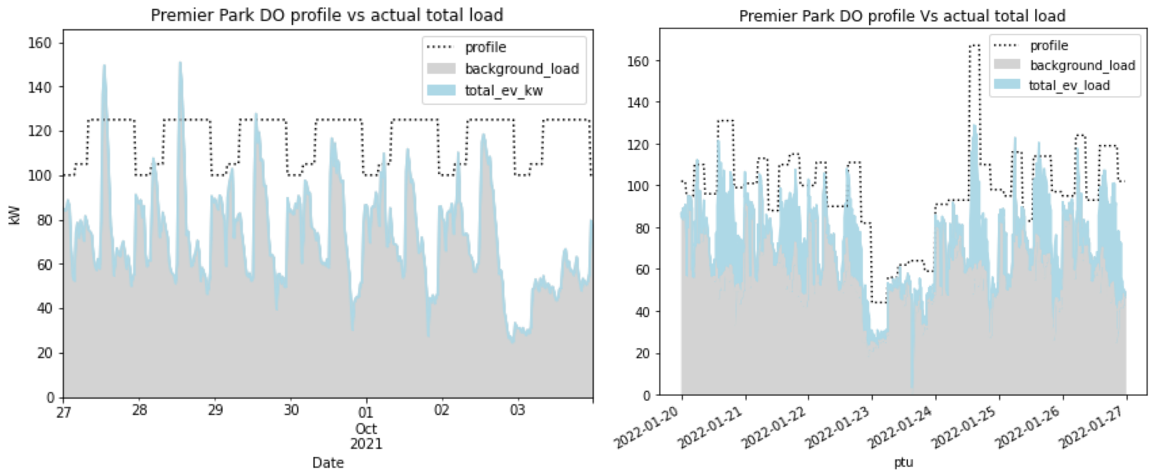
The other delivery offices have a large background load when compared with EV load (i.e. EV load < (Max(Background Load) x1.1) – Min(Background Load)) and were therefore discounted from further Profiled Connection trials, in order to focus on other trial experiments.

Premier Park has a relatively large fleet of CPs and EVs (49 EVs with 51 CP sockets), while at Victoria there are fewer (12 EVs with six CP sockets), but they are located in a car park on its own MPAN (Meter Point) and with few other loads.

The aim of this test was to evaluate whether the profile should be tested over a longer term (three or more months) at one or both depots to provide a longer-term view of profiled connection compliance.

At the Premier Park Delivery Office, the original profiled connection methodology resulted in a profile that was on average 45% higher than the load, resulting in charging not being constrained. The revised profile, incorporating actual observed charging data, as shown in Figure 124 more closely follows the load in the test period and resulted in charging being more controlled.

Figure 124 – First (left graph) and second revised (right graph) profiled connection at Premier Park Delivery Office



Breaches of the profile did occur (again at 2%, or two half hours (HH) every two days, averaging 5 kW), although they were relatively small in size and duration, but the profile was, on average, 24 kW higher than the load (compared with 45 kW in the first trial). The volume of power delivered to EVs was also analysed and was broadly consistent between the test period and the same days over the previous two months. Therefore, it was decided to take forward testing of the revised profile to a longer period.

The test at Victoria was inconclusive, as it revealed inconsistencies in the power reporting of CPs. Some CPs were not correctly reporting when charging sessions had ended, resulting in the reporting of charging appearing to continue until the vehicle is unplugged. Profiled connection testing at Victoria will resume when the issue with the CPs is resolved.

5.4 Key learnings

5.4.1 Learnings from the trial activity

The following key learnings have been derived from profiled connection trial activities:

5.4.1.1 Profiled connection implications

Determining an accurate profile is key to being able to adhere to the profile

EV load history should ideally be used to design the profile, because using telematics return times will not match actual charging, leading to inaccuracy when using those schedules to define a profiled. If a profile is initially set using estimated data based on telematics, before

EVs are operating at the site, allowances may have to be made to re-profile once actual demand is known.

Profiled connections may need to be refined as charging data becomes available

Related to the above finding, alternatively, as representative EV charging data may not be available when planning the initial connection, it may be necessary to refine the profiled connection once the EVs are in place, routines have been set and data from actual operations gathered. Similarly, the profile may need to be revised if there are material changes to the EV operations at the depot. The DNO might offer products to 'top up' or 'give back' capacity, to the network, when more accurate charging data is available and/or to account for seasonal variability in demand loads.

5.4.1.2 Changes to operations

The arrival of a new wave of EVs at a depot, following initial or extended connection, will impact the profile

For example, at five of the depots, during December and January trials, new EVs arrived and were being charged on existing infrastructure (and in some cases following an alternate day charging regime) resulting in a higher utilisation of the CPs. While profiles will generally manage some variation in EV demand, in some cases the profile may have to be revised to cope with demand from the additional vehicles. Changes in background load could also impact compliance with the profiled connection and will change the proportion of EV to background load.

5.4.1.3 Relative size of EV load to building load

Adequate EV load, in proportion to background load, is needed for a successful profiled connection. Controllable EV load needs be greater than the variation in building load

A few CPs within a large or varying building load will likely be lost in the 'noise' and controlling them, to an offered profile, will not have a meaningful impact on the adherence to a profile. If EV charging is to be used to control a profile, controllable EV load must exceed the potential variability in background load.

Ability of EVs to manage load will vary throughout the day

Not all PTUs will have EV load to manage and unless the site is primarily an EV site (e.g. a car park with few other loads, or a dedicated supply for EVs), then the majority of the time a profile will not be affected by EV smart charging. Based on the Royal Mail depots in the trials, it is estimated that EV load will be able to manage the site load in up to 15% of PTUs (or 3.5 half hours) once the site is fully electrified. This will vary at sites with different operating schedules, quantities of EVs and EV load profiles.

In summary, the primary goal of the profiled connections trial is to test whether EVs, as an additional load at a depot, can be controlled in order to adhere to an agreed profile. Profiled connections can manage this additional load caused by the EVs, but cannot, be expected to provide flexibility at times when peak demands are caused by other loads on the site.

5.4.2 Considerations for the business case for profiled connections

Optimise Prime is continuing to develop its understanding of how a profiled connection product will need to be structured as the trials progress. A number of key aspects are being considered as part of the analysis of how profiled connections can be implemented to provide benefits to both the DNO and connecting customer:

The cost and timeliness of providing profiled connections is key to creating a successful profiled connections product

The aim of a profiled connection is to reduce cost and/or lead time for the connecting customers. If the requirements of implementing a profiled connection are too costly, or onerous, customers may opt for a standard connection or indeed delay electrification. This is especially true at smaller LV connected sites, where the reinforcement cost may be lower, and the cost of implementation may be higher in proportion to the overall cost of electrification.

For the trials, UK Power Networks implemented monitoring on its network, at the customer sites or the supplying substation if the latter arrangement was feasible. This process was much more time consuming than originally envisaged, due to the need to gain agreement with the customer for the siting and installation of equipment and the need to ensure the site was suitable for installation. Two of the sites were omitted from the installation programme, as physical constraints prevented installation. Optimise Prime is considering whether other approaches to connection monitoring would be more effective.

If a customer requests a profiled connection which is to be complied with by smart charging, there may be additional risks to the DNO that need to be considered in the connection planning process

In order to actively control EV load through profiled connections, the profile needs to be set at a level that is close to actual demand. There is a risk that there could be unexpected peaks in background demand that cannot be controlled by the EV load. The DNO will need to consider this when assessing profiled connection requests – either by requiring a higher profiled connection to remove this risk, resulting in less effective reduction of EV load, or by ensuring there are other mitigations in place to protect network integrity.

Contractual, operational and technical measures may be needed to enable profiled connections, but they need to be carefully designed to ensure the product is attractive to customers

At present, the DNO has relatively few ‘levers’ to ensure customers stay within their agreed connection limits. With profiled connections, the customer may agree to use a load that is significantly less than the physical capacity of their connection, and closer to actual capacity. As a result, the potential risk to the DNO may be higher and alternative solutions such as enhanced monitoring, certification of control systems, new contractual agreements or load limiting devices may be needed.

In designing and implementing these solutions it is important to ensure that they do not impose additional risk on the customer that may outweigh the benefit of adopting the profiled connection. For example, while automatic disconnection of sites through a device, such as a G100 relay, may have relatively little side effect when used to control only generation assets, if the same methodology were applied to load, without additional safeguards, the impact on the customer’s business could be substantial. It is also necessary to ensure that the costs and configuration effort involved in implementing such a system are commensurate with the benefits for both parties.

Flexibility may be required to accommodate changes in demand over time

Variation in background demand and EV demand was seen at the Royal Mail depots between the time at which data to create the original profiles was collected and the time at which profiles were tested. Businesses are likely to vary their operations over time, and times of change such as during the introduction of EVs may be particularly unpredictable. Profiled connections should either be sized with future growth in mind or there must be a mechanism to re-evaluate profiled connections, or provide additional/reduced capacity to customers when needed. This is in line with Ofgem's Access and Forward-Looking Charges Significant Code Review, which proposes that time-profiled access rights are subject to defined triggers for review.

Fleets need to be mindful of their future electrification requirements and have full electrification in mind. Fleets should consider implementing a profile based on full fleet electrification, even if the profile is larger than what is required at the time

When implementing a profiled connection, depot managers need to plan ahead for the future electrification of their fleets. If a connection is agreed based on only a small number of vehicles the process of revision may delay future rollout – and there is a risk that sufficient capacity is no longer available when fleet expansion needs to happen. Optimise Prime's Site Planning Tool can help fleet managers understand the impact of different fleet scenarios.

Alternatively, where constraints are known to exist that will prevent full fleet electrification, profiled connections could be considered as a temporary solution until reinforcement is needed.

5.5 Next Steps

The profiled connections trials are ongoing and the results from the revised methodology will be studied and the profile updated if it should prove necessary.

Analysis of the outcomes will help the Optimise Prime project team make recommendations for the future use of profiled connections. The project aims to identify the circumstances where profiled connections can create the most benefit for DNOs and connecting customers; propose the technical and commercial requirements for the successful operation of profiled connections and quantify the benefits that the method will produce.

The project will also consider how Profiled Connection may complement or compete with the Flexibility products being trialled.

6 Commercial EV loads at domestic properties

6.1 Residential charging methodology

6.1.1 Lack of industry solution

Home-based fleets require a mechanism to separate the commercial electricity usage for charging a work vehicle from the domestic consumption on the same connection. This is necessary so that drivers can be reimbursed the right amount by their employer. The splitting of commercial load from domestic load is key to Optimise Prime's Method 1, in order to allow businesses to pay for charging taking place at a driver's home and to take advantage of flexibility services and tariffs.

When Optimise Prime was conceived, it was expected that the proposed Balancing and Settlement Code (BSC) modification P379 'Multiple Suppliers through Meter Splitting' would provide an industry solution[26]. P379 was expected to enable competition for behind-the-meter energy volumes measured by the same boundary Metering System, allowing multiple suppliers to supply the same customer. Consequently, it was expected that it would enable separation of supply to a CP and the rest of the household demand, allowing separate billing as well as an application of a different tariff to the charging demand via industry systems. This would have greatly reduced the transactional costs for fleets as compared to manual workarounds required in the absence of an industry solution.

However, P379 was withdrawn on March 10, 2021, based on a Cost Benefit Analysis, which concluded that the cost of implementing such a solution into industry systems and processes outweighs the benefits.

Other potential approaches to achieving separately metered EVs at domestic premises could include installing a secondary meter or additional MPAN, if sufficient fuseways exist at the customer premises, or utilising a measured Central Management System (mCMS) to meter EVs connected to an unmetered supply, as is currently used for CPs connected to lampposts.

6.1.2 Separation of billing for commercial loads – Centrica's solution

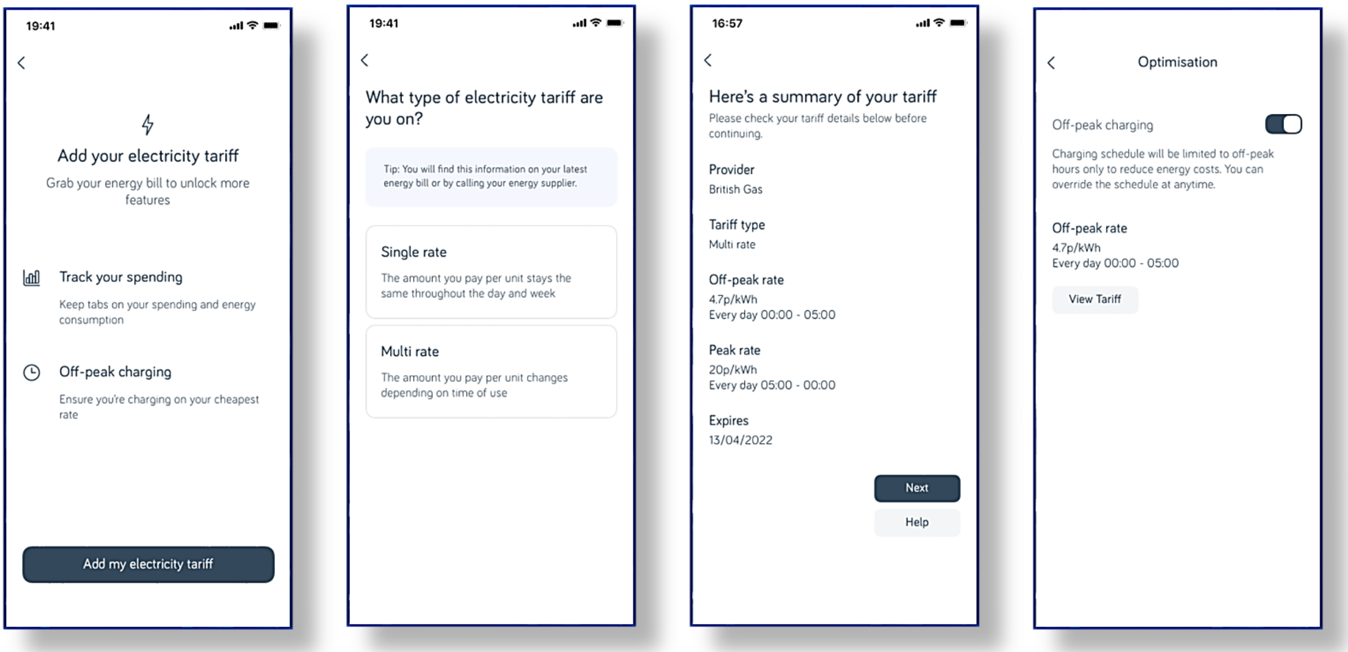
Centrica has developed a proprietary solution to enable billing for commercial loads on domestic connections, which is being implemented for British Gas fleet in parallel to the Optimise Prime project. It is also being offered as a commercial proposition to Centrica's business clients. The project captured feedback on the solution as part of the behavioural questionnaires. Prior to the implementation of this solution, British Gas operated a manual process for the measurement and reimbursement of home charging. This system was judged not to be sufficiently scalable to cope with the electrification of the whole fleet.

Currently, British Gas engineers pay their respective electricity suppliers for the whole household electricity consumption, including the CP consumption, and are then reimbursed by Centrica for the electricity used for charging based on the usage and the tariff they are on. Centrica/British Gas do not recommend a specific electricity tariff or supplier; this information must be provided by the driver to ensure correct reimbursements. To enable this, drivers are required to keep this information up to date, either by updating it on an app (see Figure 125 for an example of the user interface) provided as part of the solution, or by e-mailing their

[26] Elexon, P379 'Multiple Suppliers through Meter Splitting', https://www.elexon.co.uk/mod-proposal/p379/. [accessed on 19.01.2022]

electricity bills to an appointed contact point. This enables optimisation against the tariff, for British Gas drivers with a Time-of-Use tariff.

Figure 125 – British Gas driver app interface for tariff and optimisation management



Home tariff management for single and multi rate tariffs

Example tariff – any tariff available on the market can be entered

Tariff optimisation is currently being trialled with British Gas drivers

Usage data for purposes of reimbursements is automatically obtained from the CPs by Centrica's systems. The CPs have a MID rated meter included for measuring consumption. They also have a secondary MID rated DIN mounted meter for a manual back up to ensure data accuracy.

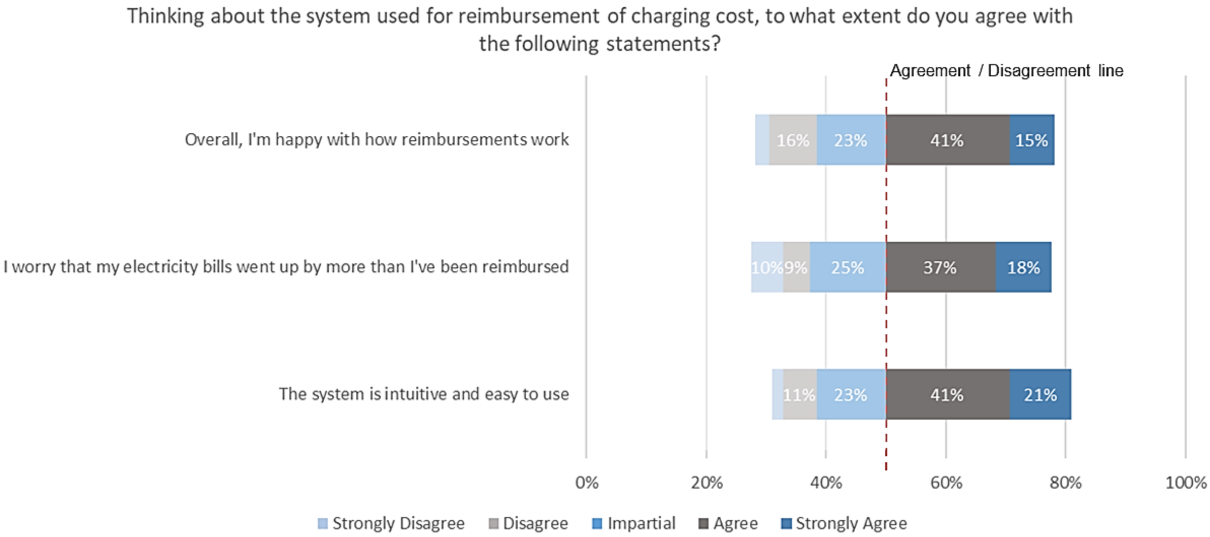
As some drivers also use the CPs to charge their personal EVs, and this is expected to increase with EV uptake, the system verifies if the vehicle charging is a work vehicle. This is enabled by prompting drivers to select the vehicle when starting the charge on the platform. Telematics also detects the battery SoC at the start and end of a charging session, and whether the vehicle is receiving power. This can be used to verify which vehicle is being charged, if the EV is receiving charge and if the charge is deemed reimbursable. No identification is required at the CP as this decision is made by the platform. 'Plug and Charge' technology, part of the ISO15118 standard and supported by OCPP 2.0 will reduce this complication by allowing the CP to identify the vehicle, but thus far no commercial vehicle has that feature.

Currently, all British Gas drivers are either on a single flat or a ToU electricity tariff, but the system is capable of managing most types of dynamic tariffs as well.

The system is integrated with the British Gas payroll system, allowing automated processing of reimbursements. This has significantly lowered the transactional cost of this process for Centrica. It is estimated that the previous manual process would have required one to two dedicated FTEs to administer it once the whole fleet electrified, and thus have a significant impact on the TCO of transition. The current process requires approximately 0.5 hours a day, mainly to perform checks and approvals, which can be absorbed by the existing fleet management roles.

However, despite the robustness of the metering process and the checks built into the system, challenges with system acceptance by the drivers were identified as part of behavioural research. As shown in Figure 126, while 79% of drivers were satisfied or expressed no opinion on the process overall, 55% expressed a concern that they are not getting reimbursed the right amount. Centrica's investigation identified only two cases of incorrect payment, which were due to a CP failure, but the concerns seem to be quite widespread. This underscores the need for communication and building trust in the system.

Figure 126 – Driver feedback on reimbursement



The acceptance issues may also be caused by the process design, whereby the driver needs to pay their electricity bill, including the cost of charging, which is reimbursed separately. To make this solution more acceptable to drivers, Centrica estimates the usage and reimburses the drivers ahead of the electricity bill payment, so that they are not 'out of pocket' and provides a monthly statement (example in Figure 127). Even so, concerns have been raised by drivers. Upon investigation, Centrica found that while the payments were made correctly, there was at times a low level of awareness regarding electricity costs. Also, the temporal misalignment of reimbursement and electricity bill payment contributed to the perception that the outgoing amount was more significant. This may be due a phenomenon known as 'recency bias' in behavioural economics, where disproportionate emphasis is placed on the events that are freshest in one's memory. Overcoming such perceptions can be difficult and require a significant communications effort.

Figure 127 – British Gas driver monthly statement

centrica
Electric Fleet Charging

EV Charging Monthly Statement
May 2021

Site
John Doe
Green Bank 3
Londond
N12 8AS

Commercial charging: £31.93
Standby usage*: £1.53

Amount Due
£33.46

Charger ID: BGS_1000
Tariff**: British Gas - 14.546 p/kWh
Date of Issue: June 13, 2021

* The cost of the charger's standby load (14W), is based on 24/7 power supply
** Please verify your tariff is correct (full tariff details are available in the Fleet Charging app)

Trans. ID	Plugged In	Plugged Out	Charging Duration (hh:mm)	Total kWh	Commercial Charging	Private Charging
17559	05-04 12:07	05-04 16:03	04:26	27.36 kWh	£4.02	
18013	05-05 20:34	05-06 06:22	09:22	46.33 kWh	£6.80	
18331	05-07 06:53	05-07 09:48	03:08	20.27 kWh	£2.98	
18348	05-07 10:27	05-07 16:46	03:58	43.91 kWh	£6.45	
18840	05-10 08:40	05-10 12:41	02:09	11.36 kWh	£1.67	
19042	05-10 20:20	05-11 06:43	06:07	32.42 kWh	£4.76	
19095	05-11 06:43	05-11 06:48	00:00	0.26 kWh	£0.04	
19356	05-12 07:38	05-13 07:06	07:22	72.47 kWh		£10.64
20344	05-17 06:54	05-17 13:16	06:59	44.20 kWh		£6.49
20389	05-17 14:45	05-17 16:36	01:58	12.83 kWh	£1.89	
20421	05-17 16:37	05-17 18:07	01:31	10.48 kWh	£1.54	
21169	05-20 08:30	05-20 10:16	01:55	12.14 kWh	£1.78	
				Grand Total	£31.93	£17.14

The system provides a monthly statement with the expected reimbursement amount, including detailed breakdown of the charging sessions and any charging for a private EV, if applicable

Other commercial solutions exist in the market that attempt to address this issue. However, these initially require the solution provider to take on the responsibility for the entirety of the household electricity bill, and subsequently re-charge the respective portions to the fleet operator (for EV charging), and the driver (for the remainder of the household electricity bill). This requires the solution provider to take on substantial risk, which can be mitigated by requiring the fleet operator to post collateral. Alternative approaches allowing a one-off payment using the account information only are being explored with electricity suppliers. This would allow the fleet operator to pay into the driver's customer account to cover the cost of work vehicle charging, which would be subtracted from the bill the driver receives from their supplier. This process could be run either by the fleet operator in-house or outsourced to a third party. While addressing the user acceptance problem to a large extent, this solution does not allow the fleet operator to decide which tariff would be most beneficial, independently of the tariff the household is on.

A regulatory solution, such as the ability to fit a secondary industry meter (MPAN) on one fused cutout for the CP, would allow the fleet operator to pay for EV charging directly via the standard industry processes, leaving the rest of the household supply unaffected, potentially reducing the cost of charging by negotiating tariffs across the whole fleet and more effectively making use of time of use tariff optimisation.

However, adding a second MPAN could cause concerns from the network management point of view; if each additional MPAN were assumed to have the same load as the existing connection it could potentially result in the DNO needing to plan for a doubling of demand. An area of innovation would be the development of dual rate meters and processes to support them, such that each rate can be settled under a different MPAN. Either method will ensure that load on the DNO supply cable remains the same as the standard domestic supply with an CP but allows for separated supply and energy billing.

6.1.3 Summary of learnings

Automating the reimbursement of charge-at-home electricity is necessary for larger fleets

If large numbers of vehicles are having their charging reimbursed against different tariffs, there is significant administrative overhead without automation.

Gaining the trust of drivers through clear communication is necessary for the successful implementation of reimbursement solutions

Where the driver is paying the electricity bill and being separately reimbursed by their employer, drivers are likely to have some concerns that they are not being fairly reimbursed.

There are limitations in what can be achieved through a commercial solution at present, as the driver firstly has to pay the bill and then be reimbursed

Commercial solutions enabling separate payment of the EV charging element by the fleet operator directly to the electricity supplier are being explored to address this issue.

However, such commercial solutions will not enable the CPs to be settled separately and thus will not enable the fleet operator to apply a different electricity tariff to the CP. This limits the ability of fleet operators to negotiate tariffs best suited to their fleets' demand patterns and the use of optimisation to charge during cheaper times of the day. Future developments in charging standards, such as implementation of OCPP 2.0 and ISO15118's plug and charge are expected to simplify allocation of charging and make it more accurate. However, these technologies are currently not widespread in commercial fleets.

6.1.4 Future considerations

The following have been identified as future considerations, outside of the scope of Optimise Prime:

- **Charging multiple vehicles on the same CP**, not all of them reimbursable or subject to optimisation. Currently only 16 of the 550 British Gas electric van drivers have a personal EV. As personal vehicles will increasingly convert to EVs, most drivers may be using the same CP to charge two or more vehicles. Centrica's solution caters for this possibility by prompting the user to identify the vehicle, via the app, in order to start the charge event. Telematics data can be used to check that the work vehicle received charge when selected in the app. It is expected that as OCPP 2.0 and 'plug and charge' capability becomes widespread this will simplify vehicle identification and reduce the need to reconcile multiple data sources.
- **Accounting for on-site generation –** The current system does not provide the option to reward the driver for the use of electricity generated via an on-site PV installation. Such feature will need to be developed, alongside accompanying rules for how this benefit should be accounted for and shared.
- **Demand response** – Once vehicles are used to participate in flexibility services and generate additional revenue, rules will need to be developed to share the value between the fleet operator and the driver, particularly if optimisation were to impact not only on the work vehicle, but also other vehicles used by the household. Options under consideration include the installation of dual socket CPs (with both sockets capable of 7.4 kWh, but not at the same time) or sharing savings with the drivers where demand response is

performed on their personal vehicle. Alternatively, personal vehicles could be exempt from optimisation.

6.2 Preliminary practical learnings from trials of managing commercial loads on domestic connections

Centrica trialled the management of commercial EV charging loads on domestic connections under two use cases: optimisation against a ToU tariff and the provision of flexibility services.

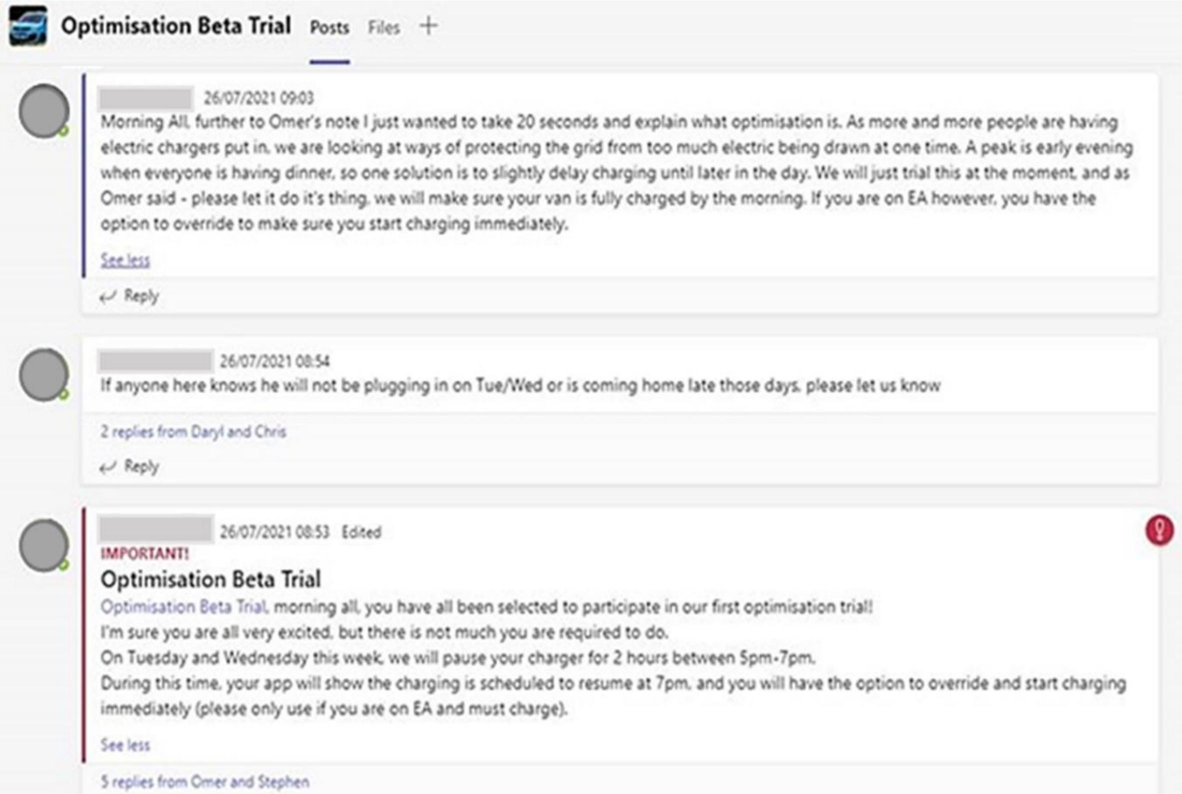
Centrica developed a system feature required to **optimise charging against a ToU tariff,** which was trialled in parallel with the Optimise Prime flexibility trials. This feature was made available to all drivers willing to use it. However, only about 3% of the drivers have a ToU tariff, and only a few have applied the schedule. Most likely, these users have a heat pump or storage heating that justified moving to ToU, because switching tariffs for the purposes of charging optimisation was not actively encouraged.

Centrica found that, despite repeated communications, many of the drivers were unaware of ToU optimisation and queried the reasons behind their charging being postponed. The drivers were able to opt-out of optimisation for one cycle (i.e. one ‘expensive’ time period) on the app. While app engagement statistics are not available, anecdotal evidence suggests this option was rarely used. It was also observed that many of the drivers did not engage with the app at all, trusting that the system will ensure sufficient charge.

The optimisation offered no benefit to the drivers, and hence there was no incentive for the drivers to engage with the process. In the future, when more drivers use the CP to charge their personal EV as well as their work vehicle, they will likely plug in their personal vehicle at the cheapest times, while leaving the work van to charge at a more expensive rate. A solution enabling separate MPANs for the CP, and the rest of the household demand, would potentially alleviate this problem, by enabling the fleet operator to apply cheaper tariffs suited to the EV charging patterns and optimising charging times more effectively.

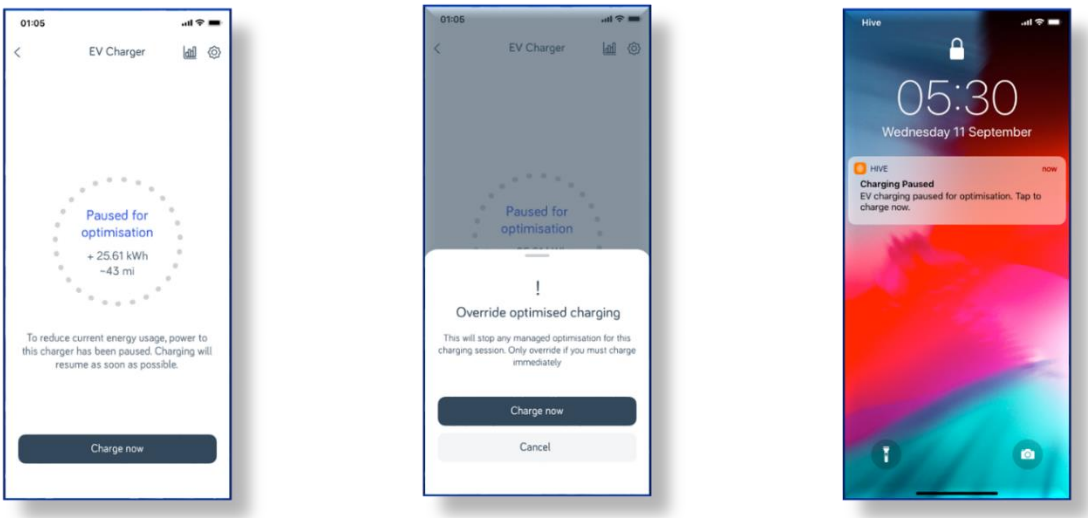
Optimisation to provide flexibility services started in October 2021 and participating vehicle numbers were increased over the subsequent periods to 300, in December events, and 500 from January 2022. Drivers with unusual shift patterns were excluded from this trial. The participants were informed about the trial, and the rationale, via e-mail and on an internal forum (see Figure 128).

Figure 128 – Centrica's communication of optimisation trials to the drivers



Similar to the ToU trial, Centrica found that despite these communications, many drivers were not aware of the trial and repeated clarifications had to be posted on the forum throughout the month following the trial's launch. The concerns were triggered either by drivers noticing that the van was not charging upon plug-in or by the optimisation alerts sent by the app (see Figure 129). As a result of driver concerns, the duration of the flex events was shortened from two hours (between 1700 and 1900) to just one hour, which was deemed more acceptable.

Figure 129 – British Gas driver app interface – optimisation for flexibility



Charging paused by the aggregator

Override option for emergencies

Real time notification

It was difficult to pitch the communications at the right level, with some drivers not engaging with optimisation at all, and others becoming interested and engaged. Engagement was required to ensure drivers opt out when needed (e.g. if they are called-out out of hours) and to exclude personal vehicles from optimisation. However, the need for engagement could be reduced if the system was able to automatically identify the vehicles and integrate with the dispatch system to ensure that the work vehicle is always sufficiently charged for the next working day.

A number of British Gas drivers have a personal EV or a plug-in hybrid and utilise the CP installed by Centrica to charge both vehicles. Complaints were received from drivers whose personal vehicle charging was paused for optimisation. To address this scenario, additional functionality was added to the app, allowing the driver to indicate if the plugged-in vehicle was a personal car, in which case the optimisation was paused. This functionality was also used to exclude personal vehicle charging from the reimbursement.

No major technical difficulties were encountered as part of this trial. Once initial issues related to control algorithms were resolved, the Alfen CPs were found to be reliable in terms of controls, scheduling and overriding. As the rollout progressed and more drivers based across the country were included, connectivity issues emerged as the main barrier to optimisation. Centrica uses cellular communications to control the CPs, which proved unreliable in locations with poor cellular coverage. This caused issues when updating the firmware version. However, this issue was no longer observed after the update.

Plug-in rates were found to be predictable during weekdays, on account of the regular shift pattern for most drivers: predictability was estimated at 95% after an algorithm learning period of three to four weeks. Weekends and holidays were more difficult to predict, quantified at 60 to 70% while vehicles were plugged in for longer and driven at irregular patterns, less often than weekdays. The estimated minimum number of vehicles necessary to accurately forecast plug-in rates was stated as 250 to 350 EVs.

Drivers can trigger an override function through the app, which stops the charging optimisation process. At the beginning of the trials, opt-out rates for smart charging sessions were high, with the charging provider Ohme seeing a noticeably high override rate. Once drivers were more aware of the process and developed trust that their vehicle would be fully charged in the morning, the opt-out rate dropped.

6.2.1 Summary of learnings

Communicating the complexities of optimisation and engaging drivers can be challenging

There is no financial incentive for drivers to smart charge company vehicles and so drivers lack motivation to take actively part in smart charging.

Integration with dispatch systems and more reliable automated identification of vehicles could reduce the need for communication and driver involvement in optimisation by increasing the confidence in the optimisation system.

Reliable communications were the key technical issue faced during implementation

Cellular communications in locations with poor coverage proved to be the most difficult technical barrier while overall CP control, scheduling and overriding performed reliably.

Plug-in rates were found to be highly predictable

Thanks to regular shift patterns during weekdays, plug-in rates could be accurately predicted with an estimated 95% accuracy. Weekends and holidays remain more challenging to predict due to irregular shift patterns. A fleet size of 250-350 EVs on domestic connections was deemed large enough to accurately forecast plug-in rates for charging optimisation.

6.2.2 Next steps

The flexibility optimisation trials are ongoing, and the results will be presented in more detail in Deliverable D7, where the impact of the project's learnings on the TCO will be discussed.

7 Market perspective on commercial EV-based flexibility services

7.1 Introduction

In order to inform the business modelling workstream, a series of interviews were conducted with flexibility market players to elicit their views on the potential of commercial fleet EVs as a source of DNO flexibility. Most of the respondents were contacted based on the published list of flexibility tenders awarded by UK Power Networks, in February 2021, with delivery dates starting in 2022. Many of the interviewees had experience of the provision of EV flexibility to DNOs in the commercial environment, as well as during innovation projects. However, only two of these had experience working with fleets of EVs as most of the value propositions focused on privately owned vehicles.

The interviews were conducted between November 2021 and March 2022. The respondents included seven Aggregators and two CPOs. A semi-structured approach to the interviews was taken, with standard questions asked at the end of each interview requiring the respondents to rate a series of statements about EV flexibility (see Section 7.4). Research based on wider market information is utilised to complement and comment on interview findings.

7.2 Perceived value of EV Flexibility

7.2.1 Minimum asset portfolio size and value per vehicle

Aggregators found it challenging to estimate a required EV portfolio size and value per vehicle, with a range from under 100 vehicles to thousands. Estimates provided a potential revenue estimate range from £20 to £250 per vehicle, which demonstrates how wide the range of value could be. Factors affecting the value per vehicle were scale, geography and ability to stack different flexibility services. Revenue stacking is often mentioned as a way to obtain higher revenue with the same number of assets. However, this requires a higher level of automation and optimisation to remove excessive manual processing tasks.

Some aggregators saw most value coming from half-hourly intraday and day-ahead trading on the wholesale energy market, with a smaller focus on DNO flexibility services. This would involve price arbitrage between times of day when electricity is most expensive and when it is cheapest. In this case, a flexibility service would be additional value, with the caveat that it may ‘cannibalise’ some of the savings generated from the price arbitrage. In short, a balancing act to achieve maximum revenue from a distributed asset class.

7.2.2 Predictability of EV asset load

The predictability of EV asset load is partly related to the minimum asset portfolio size, because a larger fleet would provide more reliable statistical predictions of potential EV flexibility. The timing requested by DNOs is critical in being able to predict EV asset load: month-ahead or longer contracts require a far larger number of assets, while within-day or day-ahead could give more guarantees for a lower number of aggregated EVs.

Depot fleets are believed to be the most predictable, with a reliable charging pattern and schedule as well as spare battery capacity between shifts. However, statistical availability methods, rather than set flexibility windows, were mentioned by certain interviewees to diminish the burden on end-customers when determining EV availability. In order to achieve a reliable level of flexibility using statistical methods, aggregators believe that the scale necessary is in the thousands or tens of thousands of EVs.

By combining domestic and commercial EV CPs, some aggregators could achieve a higher number of assets within the same portfolio. The drawback of this method is that there are additional profiles to consider within the same group of assets, thus complicating the predictability of EV load. Charging rates may vary significantly between commercial and domestic fleets, with most home CPs ranging from 3 kW (standard 13 amp plug socket) to 7.4 kW (dedicated 32 amp CP) on a single-phase connection, while commercial depots may have rapid CPs installed or a combination of both. Different vehicles are able to receive charge at different rates, particularly using AC CPs where an on-vehicle inverter is used. This is an additional variable to be considered where there is a diverse fleet of EVs.

Most aggregators combine EV assets with their wider portfolio of battery storage systems: combined heat and power (CHP), heat pumps and other assets within the same geographical area to ensure flexibility delivery. The challenge of this method is the differing peaks of utilisation between the different types of assets, which require sophisticated predictive models and delivery mechanisms.

7.2.3 Customer proposition

Some aggregators believe it may be too complicated to explain the intricacies of flexibility services to customers; flexibility planning and delivery should be automated or happen ‘behind the scenes’. In this case, the customer proposition could take the form of simple payments for plugged-in availability, or a cheaper dynamic tariff to incentivise charging during certain times. For type-of-use tariffs, where EV charging receives a cheaper rate than other electricity consumption, terms and conditions of the contract may include the availability for demand-side response (DSR) - controlled by the aggregator – as long as the vehicle then has sufficient charge for when the user needs it.

Other market participants found that the flexibility process should be transparent, including clear communication with customers, yet maintaining simplicity. When informing customers about flexibility service provisions, end-users still found the process confusing when assets do not behave in the manner expected. However, as EV adoption increases and users become familiar with their vehicles and CPs, range anxiety is expected to diminish, which may make users more comfortable with the flexibility delivery process. Simple, standardised and effective information from CP installers and aggregators, through apps and CP displays, will be useful in educating customers about the DSR process.

For public CPs, most aggregators believed that customers will expect a fast and reliable charging experience, and that there will be little room for flexibility services at these locations. Examples of customers included PHV, such as Uber drivers, as well as private vehicles requiring a rapid top-up charge. One of the interviewees suggested a potential for EV flexibility at public CPs in public parking spaces such as shopping centres or airports, where vehicles are stationed for a longer period of time, for a primary reason other than EV charging, and users can be incentivised by reduced or free parking fees in return for flexibility availability.

7.3 Main barriers in bringing EV Flexibility to the mainstream

The main barriers identified by energy aggregators in EV flexibility becoming common were scale, standardisation of technology and the ratio between value and cost. The latter appears to be affected by the complexity of delivering flexibility from EVs effectively and at scale.

7.3.1 Scale and standardisation

The number of EVs within the aggregator portfolio, in a specified DNO constraint zone, is currently difficult to achieve, meaning the value of flexibility remains low. The high barrier to access to some flexibility products, such as the Balancing Mechanism, make it un-economically to dedicate human resources to manual processes. The lack of standardisation of technology between DNOs, who use different IT systems, protocols and APIs (Application Programmable Interfaces) to request and deliver flexibility means that the flexibility execution process remains fairly manual, making it difficult to scale due to the time and resource requirements in responding to flexibility requests. This negatively impacts the value vs. cost proposition.

If scale is achieved, it will be vital to implement standard data solutions across DNOs and the transmission grid (including the transition between National Grid ESO and the newly proposed Future System Operator (FSO)). Concerns were expressed on the amount of data that will need to be collected and streamed between different platforms and marketplaces, suggesting data requirements should be reviewed regularly as more EVs are connected to the grid.

7.3.2 Customer acceptance

Customer acceptance was identified as a barrier to flexibility, particularly that delivered from public CPs. CPOs interviewed shared the view that the concept of releasing flexibility from public charging would be difficult for users to accept, with most customers just wanting to charge their vehicles at the fastest rate possible without additional complications. In Optimise Prime this would most likely be the case for PHV drivers in London who want to minimise the opportunity cost of charging. Fleet vehicles topping up in public locations would most likely also object to constraints in rapid charging, as delivery schedules would take priority.

Commercial fleets at depot locations are believed to be the most suitable to EV flexibility, due to concerns of peak loads exceeding capacity resulting in additional connection costs. Research suggests the regular shifts of vehicles returning to depots also simplify the charging forecasts, often allowing flex availability in the evenings before tariff-optimised charging at night. This is being verified through the Optimise Prime trials.

Domestic customers may need some time adapting to requests for flexibility, especially while customer propositions are still being explored. As EVs become more popular and DSR reaches the mainstream, domestic customer acceptance may become less of a challenge.

7.3.3 Metering

The availability and quality of electricity metering can be a barrier to realising the flexibility potential. Aggregators were concerned with the divergence of metering requirements between EVs and other assets (e.g. heat pumps), meaning data availability and flexibility predictions would be limited.

7.3.4 Baselining methodology and opportunity for gaming the system

The baseline methodology utilised for flexibility services is often different between the DNOs and the type of flex product. This adds to the complexity and potentially manual processes involved in scaling EV flexibility. Forward-looking flexibility provision predictions were preferred by aggregators, compared to set baselines from historical data. Additional research and trials are required to determine the extent to which the current baselining methodologies can be manipulated by the market to gain further flexibility revenue during demand turn-down, as mentioned in the UK Power Networks Flexibility Roadmap[27].

7.4 Summary of quantitative responses

Respondents were asked to rate the following statements:

On a scale from one (not confident at all) to 10 (very confident) and thinking about timescales to 2030, how would you rate the following:

a. Your confidence that DNO flexibility services will constitute a significant source of value for you in the future
b. Your confidence that commercial EVs on domestic connections will constitute a valuable asset class in terms of flexibility provision
c. Your confidence that commercial EVs on a commercial connection (i.e. depot based fleets, offices) will constitute a valuable asset class in terms of flexibility provision
d. Your confidence that public CPs (in particular, those used by commercial and private hire vehicles) will constitute a valuable asset class in terms of flexibility provision

Respondents indicated that DNO flexibility services would constitute a significant source of value for the aggregators in the future. These responses ranged from 4 to 10, with over three quarters answering between 8 and 10. The aggregator that scored this the lowest stated that they have more confidence in the value of other non-DNO products.

For commercial vehicles, based at a domestic connection, responses ranged from 5 to 10. Those who scored this the lowest had reservations on the immature market for EV flexibility and were unsure of the value from developments in flexibility services in the coming years (see Section 7.3 regarding barriers to EV flexibility).

For depot-based fleets, ratings were higher, with feedback that depots would likely have a regular schedule and charging profile that could be more easily controlled. The larger scale, combined with specific and unvaried charging locations, would provide increased value to the flexibility market.

Public CPs were rated lowest, with a range from 2 to 6, with the belief that it would be complicated to deliver flexibility through rapid public CPs in a convenient way for the customer. However, the lack of off-street charging availability near domestic properties was cited as a potential for lower speed public CP flexibility services, and rated as 6 out of 10.

7.5 Key learnings and next steps

High complexity and the level of automation required to bring down transactional cost make it likely that fleets will participate in the flexibility markets via intermediaries such as aggregators or CP operators

Direct participation by commercial EV fleets is unlikely, given the scale required and complexity involved in setting up flexibility contracts and ensuring delivery.

The main barriers identified by energy aggregators in bringing EV flexibility to the mainstream were scale, standardisation of technology and customer acceptance

[27] futuresmart-flexibility-roadmap.pdf (ukpowernetworks.co.uk)

Standardisation of technology is vital in achieving EV flexibility at scale. The value proposition is difficult to communicate to the customer. However, the offerings explored ranged from reduced charging costs to vouchers and other incentives.

The value of EV flexibility remains difficult to predict

The novelty of the market offerings, customer interest and scale make predictions difficult. However, aggregators see a strong opportunity for revenue in a timeline to 2030.

EV flexibility at public CPs was believed to be least likely to deliver value

This is due to the nature of the service provided: customers will want to charge rapidly and reliably and will not see the benefit in flexibility. This is a key implication for CPOs and DNOs given the deployment of rapid and ultra-rapid CPs within major cities.

8 Conclusions & next steps

8.1 Conclusions

This report forms the evidence for the fifth Optimise Prime deliverable. The project has successfully delivered on the requirements of deliverable D5 and this report provides a comprehensive overview of behavioural and economic factors impacting the business case for commercial vehicle electrification, together with analysis of the lessons learnt from the project methods.

This report should prove valuable to any fleet considering the transition to EVs, highlighting the key steps in the electrification journey and the financial, operational and behavioural aspects that need to be considered for a successful fleet rollout. Behavioural acceptance is key in ensuring that the complex process of change involved in fleet electrification runs smoothly. The large sample of views from drivers in businesses making an early adoption to EVs should provide reassurance in the positive reactions, while highlighting specific areas which cause problems for drivers.

Key Learnings for fleets

- There are a wide range of factors that fleet managers need to consider when transitioning to EVs. Careful planning is essential and must consider business needs, site constraints (both physical and electrical) and the management of changes to business processes. A comprehensive guide based on the experiences of the Optimise Prime partners can be found in Section 2 of this report
- At present, whether total cost of ownership (TCO) favours EV or ICEV fleets varies considerably. EV prices are the key determinant of whether EVs make purely economic sense for a fleet, but there are many other factors influencing the cost. The economic cost also needs to be weighed against the clear environmental benefits of EV adoption
- After drivers have driven EVs, they feel more positively about the technology and have positive views towards EV adoption
- Charging facilities play a key role in giving drivers the confidence that they can fulfil their daily work tasks. The lack of charging facilities can be a particular concern for drivers
- Drivers who are not happy with their EV generally have broader concerns over a range of technical, organisational, economic, and environmental aspects. There is not a single area that needs to be improved to get them ‘on board’
- Automating the reimbursement of charge-at-home electricity is necessary for larger fleets. Gaining the trust of drivers through clear communication is necessary for the successful implementation of reimbursement solutions
- Communicating the complexities of optimisation and engaging drivers can be challenging

For DNOs and regulators, this report provides important learnings about the applicability of profiled connections, that will be useful in defining plans for the use of time-profiled access rights to improve the efficient use of networks. Learnings from the implementation of home charging highlights the issues currently faced in the implementation of home charging which, though commercial work-arounds exist, could benefit from industry solutions. The report also describes the interim work carried out in order to quantify the value of the project methods for DNOs.

Key Learnings for DNOs

- While connection costs are not the major driver of electrification costs, they can contribute to making or breaking an investment case which is sometimes finely balanced
- Centrica found that the installation of home charging slowed their rollout and sometimes required drivers to use public charging as an alternative. This was generally as a result of domestic properties that were already near capacity due to electric heating, or were on 'looped' supplies
- Charging facilities play a key role in giving drivers the confidence that they can fulfil their daily work tasks. Enabling adequate charging infrastructure is crucial to the successful transition to EVs
- Adequate EV load, in proportion to background load, is needed for a successful profiled connection. Controllable EV load needs to be greater than the variation in building load. Careful consideration should be given to the suitability of a site.
- Determining an accurate profile is key to being able to adhere to the profile. Profiled connections may need to be refined as more data becomes available. DNOs may need to be flexible to review changes in requirements over time and will have to put in place contractual, operational and technical measures to manage risk
- Thanks to regular shift patterns during weekdays, plug-in rates could be accurately predicted with an estimated 95% accuracy during the home trials. This should allow provision of reliable flexibility services. Weekends and holidays remain more challenging to predict due to irregular shift patterns. A 250-300 vehicles fleet should be able to deliver this level of accuracy.
- With regard to billing of commercial EV charging at home there are limitations in what can be achieved through a commercial solution at present, because the driver first has to pay the bill and then be re-imbursed. This may benefit from an industry solution. Companies cannot easily benefit from domestic ToU tariffs.
- High complexity and the level of automation required to bring down transactional cost make it likely that fleets will participate in the flexibility markets via intermediaries such as aggregators or Charge Point Operators

The design of the Optimise Prime trials build on learnings from several other Ofgem funded innovation projects and this deliverable report ensures future Innovation projects can build on the learning from Optimise Prime.

Data capture, analysis and trialling activities will continue over the coming months and will be utilised to further develop the economic and behavioural insights presented in this report. The project's final deliverable, D7, will expand upon the findings presented in this report, and the early learning published in Deliverable D4 in order to complete the trial experiments and answer the project's core questions.

For further questions on the evidence provided in this report, or more general questions about the project, please contact Optimise Prime team at: communications@optimise-prime.com or visit the project website www.optimise-prime.com.

8.2 Next steps: Open items & future activities

The Optimise Prime trials will continue until the end of June 2022. Throughout this period the project team will focus on:

- Running executions of all of the Optimise Prime trial experiments, including analysing in greater detail on the future impacts of EVs on distribution networks, based on what the project is learning about EV use
- Utilising project data with UK Power Networks' Strategic Forecasting System in order to quantify network impacts of EV adoption and the project methods
- Continuing to trial a range of flexibility and profiled connections to prove the effectiveness of the project's methods, developing the methodology based on what has been learnt so far
- Conducting final behavioural studies related to EV adoption, and refining economic analysis of the impact of electrification fleets and DNOs, building on the findings in this report
- Continuing to collect a comprehensive dataset on EV use and charging behaviour and publishing a public dataset in Deliverable D6
- Continuing to engage with stakeholders through communications and events

9 Appendices

9.1 CP Types and charging speeds

Table 42 – CP types and charging speeds

CP Type	Charge Speed	Time needed to charge from 20% to 90% SoC		
		40kWh battery capacity EV	60kWh battery capacity EV	80kWh battery capacity EV
AC 16A single phase	3.6kW	8 hours	12 hours	16 hours
AC 32A single phase	7.4kW	4 hours	6 hours	8 hours
AC 32A three phase	22kW	1 hour 20 minutes	2 hours	2 hours 40 minutes
Rapid DC CCS	50-100kW (example calculated at 50kw)	35 minutes	50 minutes	1 hour 10 minutes
Ultra-rapid DC CCS	100+kW (example calculated at 150kW)	12 minutes	18 minutes	24 minutes

Times given are approximate and may vary due to the vehicle's on-board charging system. Not all vehicles are capable of charging at all rates, especially 22kW AC and Ultra-rapid DC.

9.2 Example calculation of EV and CP numbers

The calculations steps below are based on the Premier Park Depot. This is due to Premier Park Depot already having three different types of vehicles in their EV fleet. In order to make results comparable in the TCO, Mercedes eVito was removed from the assumed fleet and converted into eExpert. Based on the input from the project partner, the price point for eVito model was considerably higher than eExpert, therefore, having it in the TCO would not make a comparable result and assumed EV fleet would look more like an upgrade rather than conversion into EVs. Therefore, from the table below, current eVito vehicles were added to the current eExpert model. Then in order to obtain 100% EV, remaining 62 ICEVs were added to EV fleet based on the ratio of current vehicles without eVito. Regarding Assumed CP, this was calculated based on OP Partner Input where there will be one double CP purchased per four vehicles which gives ratio of 2:1, vehicle: socket.

Table 43 – Vehicles and CPs at Premier Park Depot

Premier Park (111 Vehicles)	
Current Vehicles	
ICEV	EV
62 Unknown Vehicle Model	37 ePartner
	2 eExpert
	10 eVito
Current Vehicles without eVito	
ICEV	EV

Premier Park (111 Vehicles)	
62 Unknown Vehicle Model	37 ePartner
	12 eExpert
Assumed Vehicles	
100% ICEV	100% EV
84 Partner	84 ePartner
27 Expert	27 eExpert
Assumed CPs	
28	

9.3 Reliability tests on behavioural survey responses

Since ordinal data from Likert-scale items are explored, a rigorous statistical procedure was undertaken in order to evaluate the reliability of the dataset by applying the factor analysis correctly and to determine the suitability beforehand. This includes initial tests of sampling adequacy using the Kaiser-Meyer-Olkin measure and Bartlett's Test of Sphericity. The Kaiser-Meier-Olkin measure (KMO) indicates the level of sampling adequacy. High KMO values correspond to a greater correlation among variables and a smaller partial correlation among them[28]. KMO varies from zero to one, fixing in 0.5 the acceptance threshold, in 0.7 a good level of adequacy and in 0.9 the excellence. Bartlett's test of sphericity is performed to check the null hypothesis that the original correlation matrix was an identity matrix[29].

Looking at Table 44, Table 45 and Table 46, the KMOs for each fleet and each iteration are all very close to or greater than 0.9, showing an excellent level of adequacy. The very small p-values (threshold $p < 0.001$) obtained for Bartlett's test of sphericity mean that the null hypothesis of the identity matrix can always be rejected.

Table 44 **– Reliability tests, Centrica**

KMO and Bartlett's Test			
		Iteration 1	Iteration 2
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.839	0.914
Bartlett's Test of Sphericity		1398.481	3683.976
	df	325	435
	Sig.	<0.000001	<0.000001
Number of Observations:		97	230

[28] Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika*, *39*(1), 31–36.
[29] Bartlett, M. S. (1951). The effect of standardization on a χ 2 approximation in factor analysis. *Biometrika*, *38*(3/4), 337–344.

Table 45 – Reliability tests, Uber

KMO and Bartlett's Test			
		Iteration 1	Iteration 2
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.93	0.93
Bartlett's Test of Sphericity		10389.976	13212.396
	df	325	325
	Sig.	<0.000001	<0.000001
Number of Observations:		798	952

Table 46 – Reliability tests, Royal Mail

KMO and Bartlett's Test			
		Iteration 1	Iteration 2
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.848	0.835
Bartlett's Test of Sphericity		1882.374	1388.288
	df	171	171
	Sig.	<<0.000001	<<0.000001
Number of Observations:		312	209

EFA was conducted by extracting the factors with Principal Axis Factoring and rotating them with "Varimax orthogonal rotation" in order to simplify the correlation among the items of each factor. Extraction and rotation produced the factor loading matrix and the factors were identified based on the similarity of the factor loading values.

For the cross-fleet analysis, shown in Table 47 and Table 48, the KMOs for each iteration are all very close to 0.9, showing a very good level of adequacy. The very small p-values (threshold p <0.001) obtained for Bartlett's test of sphericity mean that the null hypothesis of the identity matrix can always be rejected.

Table 47 – Reliability tests, EV Drivers

EV driver			
		Iteration 1	Iteration 2
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.854	0.870
Bartlett's Test of Sphericity		1964.172	4170.207
	df	120	120
	Sig.	<<0.00001	<<0.00001
Number of observations		302	634

Table 48 – Reliability tests, Non-EV Drivers

Non-EV driver			
		Iteration 1	Iteration 2
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.868	0.87
Bartlett's Test of Sphericity		5441.244	4788.798
	df	120	120
	Sig.	<<0.00001	<<0.00001
Number of observations		879	757

9.4 EFA Results

Table 49 – EFA, Centrica

		Centrica											
		Iteration 1						**Iteration 2**					
		Factor loadings						Factor loadings					
FAST	ITEM	Benefits of EV to the organisation	Compliance to external expectations	Impact of electrification on work tasks	Considerations of drivers' perspective	Opinion on driving experience		Benefits of EV to the organisation	Compliance to external expectations	Impact of electrification on work tasks	Considerations of drivers' perspective	Opinion on driving experience	Pro-smart charging
Management involvement and training	MI1	0.404					MI1				0.455		
	MI2				0.506						0.535		
Organisational structure	OF1				0.691						0.843		
	OF2				0.875						0.789		
Electric vehicle performance	PE1					0.576						0.701	
	PE2			0.459		0.643						0.682	
	PE3	0.449											
	PE6						PE6			0.45			
Effort related to EV adoption	EA1			-0.845						-0.741			
	EA2			-0.654						-0.766			
	EA3			-0.669						-0.581			
	EA4							-0.423					
	EA5						EA5						-0.485
Attitudes/emotions & social influence	AI1	0.645						0.589					
	AI2	0.852						0.826					
	AI3	0.848						0.78					
	AI4	0.47				0.672		0.439				0.576	
	AI5	-0.484						-0.588					
	AI6			0.79						0.486			
	AI7												
	AI8	0.605						0.487					
	AI9	0.553						0.483	0.426				
	AI10		0.551						0.619				
	AI11						AI11		0.669				
	AI12		0.614						0.753				
	AI13		0.864						0.766				
	AI14		0.478						0.534				
	AI15		0.509						0.577				
	AI17						AI17						0.414
	AI18						AI18	0.434					0.611

Table 50 – EFA, Uber

		Uber										
		Iteration 1						**Iteration 2**				
		Factor loadings						Factor loadings				
FAST	ITEM	Benefits of EV to the organisation	Compliance to external expectations	Impact of electrification on work tasks	Considerations of drivers' perspective	Opinion on driving experience		Benefits of EV to the organisation	Compliance to external expectations	Impact of electrification on work tasks	Considerations of drivers' perspective	Opinion on driving experience
Management involvement and training	M1				0.736						0.753	
	MI2				0.801						0.798	
	MI3				0.719						0.756	
Electric vehicle performance	PE1					0.653		0.423				0.616
	PE2					0.644						0.611
	PE3					0.573						
	PE4					0.411	PE4	0.524				
	PE5	0.511				0.433		0.644				
Effort related to EV adoption	EA1			0.688						0.75		
	EA2			0.741						0.817		
	EA3			0.79						0.764		
Attitudes/emotions & social influence	AI1	0.442						0.552				
	AI2	0.624						0.762				
	AI3	0.479	0.442					0.668				
	AI4		0.437			0.596		0.484	0.429			0.497
	AI5	-0.445										
	AI6											
	AI7											
	AI8		0.49			0.446	AI8	0.546				
	AI9		0.619						0.603			
	AI10		0.723						0.685			
	AI11		0.694						0.675			
	AI12		0.63						0.746			
	AI13		0.602						0.672			
	AI14		0.689						0.651			
	AI16		0.619						0.534			0.406

Table 51 – EFA, Royal Mail

		Royal Mail										
		Iteration 1						**Iteration 2**				
		Factor loadings						Factor loadings				
FAST	ITEM	Benefits of EV to the organisation	Compliance to external expectations	Impact of electrification on work tasks	Considerations of drivers' perspective	Opinion on driving experience		Benefits of EV to the organisation	Compliance to external expectations	Impact of electrification on work tasks	Considerations of drivers' perspective	Opinion on driving experience
Management involvement and training	MI1				0.772						0.77	
	MI2				0.611						0.549	
Electric vehicle performance	PE1					0.849						0.635
	PE2					0.7					0.486	0.516
Effort related to EV adoption	EA1			0.699						0.537		
	EA2			0.677						0.879		
	EA3						EA3			0.434		
	EA4			0.407								
Attitudes/emotions & social influence	AI1					0.402						0.588
	AI2	0.589						0.757				
	AI3	0.508						0.714				
	AI4					0.687						0.757
	AI5	-0.498										
	AI6		0.433						0.41			
	AI9		0.604						0.792			
	AI10		0.661						0.629			
	AI11		0.67						0.718			
	AI14		0.671						0.524			
	AI15		0.431									

Table 52 – Factor Loadings, EV Drivers (cross-fleet analysis)

		EV drivers										
		Iteration 1						**Iteration 2**				
		Factor loadings						Factor loadings				
FAST Framework	ITEM	Benefits of EV to the organisation	Compliance to external expectations	Impact of electrification on work tasks	Considerations of drivers' perspective	Opinion on driving experience		Benefits of EV to the organisation	Compliance to external expectations	Impact of electrification on work tasks	Considerations of drivers' perspective	Opinion on driving experience
Management involvement and training	MI1				0.834						0.79	
	MI2				0.592						0.717	
Electric vehicle performance	PE1					0.816						0.772
	PE2					0.612						0.742
Effort related to EV adoption	EA1			0.832						0.751		
	EA2			0.723						0.807		
	EA3			0.456						0.637		
Attitudes/emotions & social influence	AI1	0.464						0.468				
	AI2	0.653						0.73				
	AI3	0.544						0.684				
	AI4					0.701						0.636
	AI5											
	AI6						A16			-0.401		
	AI9		0.536						0.608			
	AI10		0.727						0.727			
	AI11		0.776						0.647			

Table 53 – Factor Loadings, Non-EV Drivers (cross-fleet analysis)

		non-EV drivers									
		Iteration 1					**Iteration 2**				
		Factor loadings					Factor loadings				
FAST Framework	ITEM	Benefits of EV to the organisation	Compliance to external expectations	Impact of electrification on work tasks	Considerations of drivers' perspective	Opinion on driving experience	Benefits of EV to the organisation	Compliance to external expectations	Impact of electrification on work tasks	Considerations of drivers' perspective	Opinion on driving experience
Management involvement and training	MI1				0.698					0.642	
	MI2				0.824					0.802	
Electric vehicle performance	PE1					0.702					0.739
	PE2					0.738					0.645
Effort related to EV adoption	EA1			0.696					0.551		
	EA2			0.765					0.744		
	EA3			0.792					0.637		
Attitudes/emotions & social influence	AI1	0.483									
	AI2	0.713									
	AI3	0.61									
	AI4					0.555					0.58
	AI5										
	AI6										
	AI9		0.607					0.614			
	AI10		0.729					0.754			
	AI11		0.654					0.669			

9.5 Details of Novuna customer behavioural analysis

This appendix provides the detailed analysis of behavioural surveys of Novuna Vehicle Solutions customer fleets, summarised in Section 4.4.

9.5.1 Factor analysis of the Novuna fleets

The investigation of the FAST construct for Novuna fleets is performed with Exploratory Factor Analysis on 30 statements, which are the same as those presented to Centrica's drivers (iteration two) and shown in Table 33, from a total of 105 (out of 107) drivers with complete responses. Unlike what has been done for the project's partner fleets, in this case the limited number of responses for each fleet (51, 28 and 26) does not allow a separate EFA to be performed for each of them. Therefore, the Novuna fleet is considered for the factor analysis as a single group.

It should also be stressed that, considering that only 16 out of 105 responses come from EV drivers, the following results refer to a population of predominantly non-EV drivers. EV and non-EV drivers have been combined for the analysis presented here. To verify the outcomes, a separate factor analysis was also completed for the set of 89 non-EV drivers. The results of this analysis is not presented here as they were almost identical and the number of EV drivers is too small to determine statistically significant differences.

Table 54 indicates that there is high reliability in the sample including all three fleets. The KMO measures for each iteration are all close to 0.9, showing a good level of adequacy. The small p-values (threshold $p < 0.001$) obtained for Bartlett's test of sphericity mean that the null hypothesis of the identity matrix can always be rejected.

Table 54 – Reliability tests, Novuna

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.873
Bartlett's Test of Sphericity		2160.678
	df	435
	Sig.	0

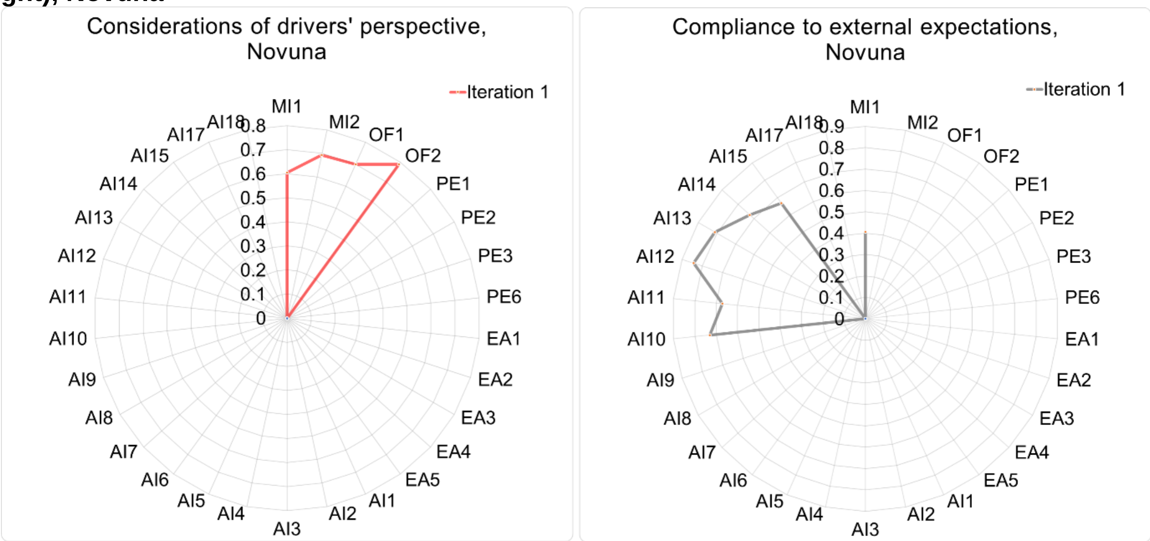
The results of the exploratory factor analysis (EFA) are shown in Table 55, detailing the factor loadings for all relevant statements, with a threshold of 0.4. The outcome is similar to the previous three fleets for Uber, Centrica and Royal Mail. It is possible to identify five factors that are in line with the discussions presented for those fleets, namely: Benefits of EV to the organisation, Compliance to external expectations, Impact of electrification on work tasks, Consideration of drivers' perspective and Opinion on driving experience.

Table 55 – Factor Loadings of the Novuna vehicle fleets

FAST	Item	Factor loadings: Benefits of EV to the organisation	Compliance to external expectations	Impact of electrification on work tasks	Considerations of drivers' perspective	Opinion on driving experience
Management involvement and training	MI1		0.406		0.604	
	MI2				0.692	
Organisational structure	OF1				0.7	
	OF2				0.79	
Electric vehicle performance	PE1					0.62
	PE2					0.861
	PE3	0.458				
	PE6	0.565				
Effort related to EV adoption	EA1			0.709		
	EA2			0.698		
	EA3			0.814		
	EA4			0.463		
	EA5			0.423		
Attitudes/emotions & social influence	AI1	0.713				
	AI2	0.729				
	AI3	0.73				
	AI4	0.647				
	AI5					
	AI6	0.478				
	AI7	0.661				
	AI8	0.763				
	AI9	0.784				
	AI10		0.73			
	AI11		0.672			
	AI12		0.843			
	AI13		0.811			
	AI14		0.726			
	AI15		0.668			
	AI17	0.491				
	AI18	0.624				

Similar to the Centrica results, in the second iteration, the factor “Considerations of drivers' perspective” (shown in Figure 130, left) explains the variance of the statements included in the two FAST framework constructs: “Management involvement and training” (MI) and “Organisational structure” (OF). This indicates that the drivers appear to be involved at different levels to understand the changes in the organisation required when transitioning to EVs. They believe that information is communicated efficiently by the organisation and managers (MI1 – Our shift to electric vehicles is supported by sufficient information and training provided by our organisation and MI2 – Our managers are implementing strategies and technologies to ensure that the switch to electric vehicles has minimal impact on our tasks); they are consulted (OF1 – Drivers' inputs are considered when new vehicles, navigation technologies or other technological changes to are adopted by our organisation and OF2 – Drivers are consulted when new vehicles, navigation technologies or other technological changes are adopted by our organisation). Therefore, their perspectives can influence the companies' decisions. The loadings for MI1 and MI2 are slightly higher than for Centrica, and all four statements here have a more similar weighting to each other.

Figure 130 – Consideration of drivers' perspective (left) compliance to external expectations (right), Novuna

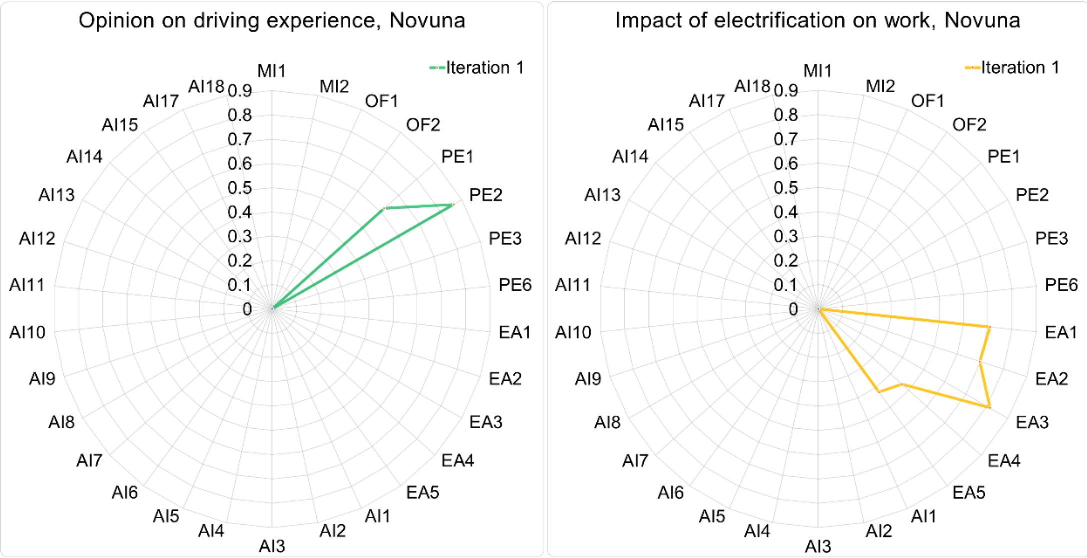


The two factors: "Compliance to external expectations" (Figure 130, right) and "Opinion on driving experience" (Figure 131, left) also agree with the conclusions of the other fleets. The first factor demonstrates that drivers are conscious of the transition to EVs that is targeted by government (AI13) and other businesses (AI10, AI12 and AI15), and that customers expect a switch to EVs (AI14). The statement on information and training provided (MI1) is above the threshold, which was not the case for the other fleets, which suggests that external expectations are communicated well from within the organisation. However, it is important to note that the MI1 statement is mostly involved in the explanation of the factor: "Considerations of drivers' perspective" for which its factor loading is much higher (i.e. 0.604).

For the factor: "Opinion on driving experience" (Figure 131, left), the two key statements: "Driving an electric vehicle is more pleasant as it is less noisy than a conventional vehicle" (PE1) and: "The acceleration performance of the electric vehicles is very good" (PE2). In this case, importance is particularly given to acceleration. Views of the drivers on whether EVs are 'cool and pleasant to drive' (AI4) do not appear to play as much as a role for Novuna customers, as Centrica. In this analysis, the factor on 'benefits to the organisation', instead of for the driver, reflects the image of the company rather than the driver's experience. It should be noted that this is based on all responses where the overall majority does not currently drive an electric vehicle and so answers are based on expectations or influenced by experiences of others.

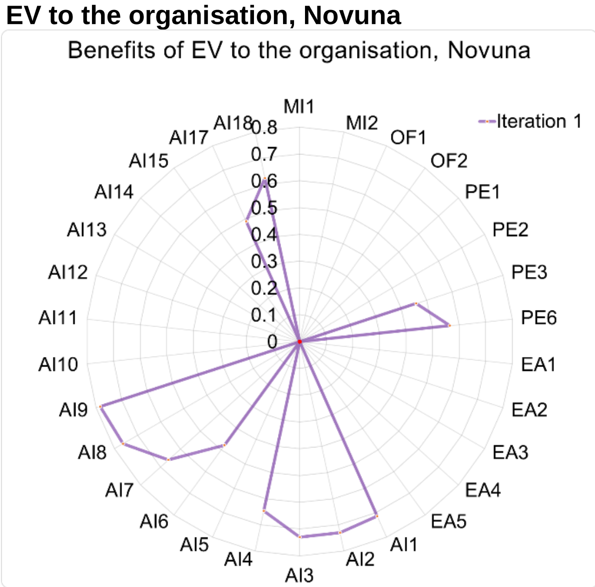
Contrasting to Centrica's results, the three statements on smart charging (EA5, AI17 and AI18) do not group together in a single factor. An EFA solution with six factors (rather than five) was tested to see if smart charging statements could be grouped. This was not possible and it did not show a new, stand-alone factor on pro smart charging attitudes (as in the case of Centrica's iteration two). This difference might be because these three statements (EA5, AI17, AI18) were presented during the second Centrica survey when drivers could have been more exposed to EV technology and had a better understanding of the smart charging and its specific benefits. This cannot be observed in Novuna's results given the small number of EV drivers.

Figure 131 – Opinion on driving experience (left) and impact of electrification on work (right), Novuna



The two statements: "It is difficult to remember to plug-in the electric vehicle at the end of the day/shift" (EA4) and "Smart charging is risky – there may not be enough charge when the driver needs it" (EA5) load onto the factor: "Impact of electrification on work tasks" which now corresponds to the group of statements: "Effort related to EV adoption". This indicates that, during this iteration across Novuna fleets, drivers are concerned about all the different issues related to EVs that can affect the work tasks, which are in order of importance based on factor loading magnitude (as seen in Figure 131, right): limited availability of charging facilities (EA3), limited range (EA1), long charging (EA2), difficulty remembering to plug-in (EA4) and risks of smart charging (EA5). The free-text comments also confirm that drivers are concerned about range and access to charging points (both at home, and while away on the job) and that these might be obstacles even though the driver would otherwise be keen on an EV.

Figure 132 – Benefits of EV to the organisation, Novuna



The other two statements related to smart charging (AI17 and AI18) relate to the factor: "Benefits of EV to the organisation" (Figure 132). This is the factor characterised by the greatest number of statements (12) from the FAST framework constructs: "EV performance" (PE) and "Attitudes/emotions & social influence" (AI). Based on the magnitude of the factor loadings, it is of particular importance the attitudes about the company's good public image given by EVs (AI9), the advantage given by the low energy cost (AI8), the benefit to the environment in the long term (AI2) and their propensity to be interested in EV (AI1).

Key insights from the factor analysis of the Novuna customers:

- Novuna drivers are involved at different levels to understand the changes in the organisation that are part of the switch to EVs. They believe that information is communicated efficiently by the organisation and managers and are consulted.
- Drivers are conscious of the transition to EVs that is targeted by government and other businesses, and that customers might also expect a switch to EVs.
- Driver's opinion on EV driving experience is clearly affected by EV acceleration and noise.
- Given the population of mostly non-EV drivers, there is particular concern about limited availability of charging facilities, limited range, long charging.
- The company's improved public image from the switch, the advantage of lower energy costs, the benefit to the environment in the long term are perceived as the most important benefits of EVs to the organisation.

9.5.2 Novuna EV vs non-EV drivers

The small sample does not allow a reliable EFA to be performed separately for the EV drivers, as only 16 drivers in this data set are EV users. Therefore, a frequency analysis has been performed to understand if there are potentially interesting differences in response between the two. A factor analysis has been performed on the non-EV drivers, which gave similar factor loadings as shown in Table 55 for the entire dataset.

Comparing the percentages from the chart below (Figure 133 for non-EV drivers, and Figure 134 for EV-drivers), a higher percentage of EV drivers believes that the performance of EVs are better than conventional vehicles, especially regarding noise (PE1, more than 40% of EV drivers mostly or entirely agree) and acceleration (PE2, more than 80% of EV drivers mostly or entirely agree).

Additionally, 40% of EV drivers entirely disagree with the possibility to forget to plug-in (EA4); almost 30% entirely disagree with the fact that the limited range might affect the daily work task (EA1), and only 15% mostly or entirely agree that smart charging is risky (EA5).

Figure 133 – Frequency analysis - non-EV drivers

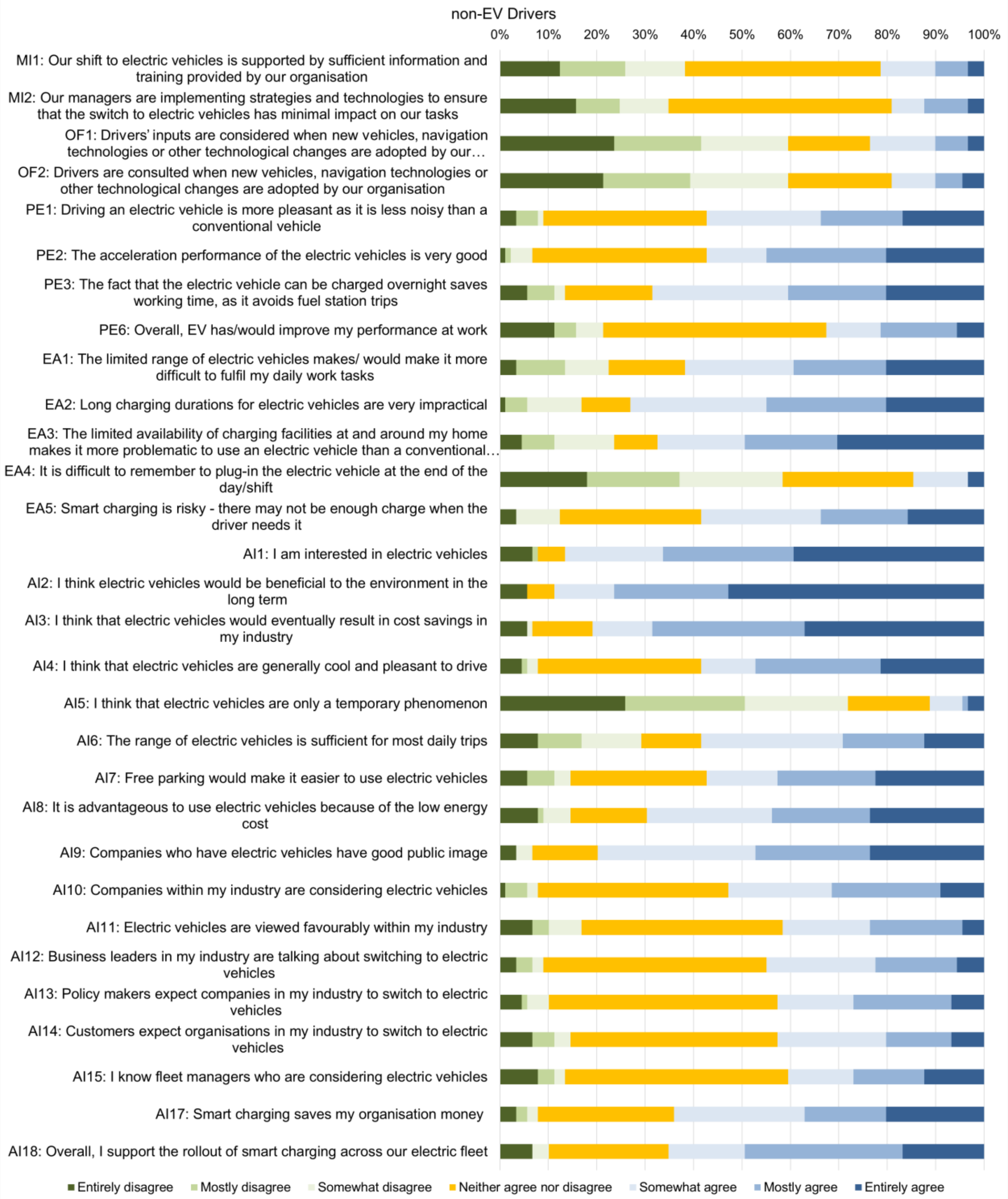
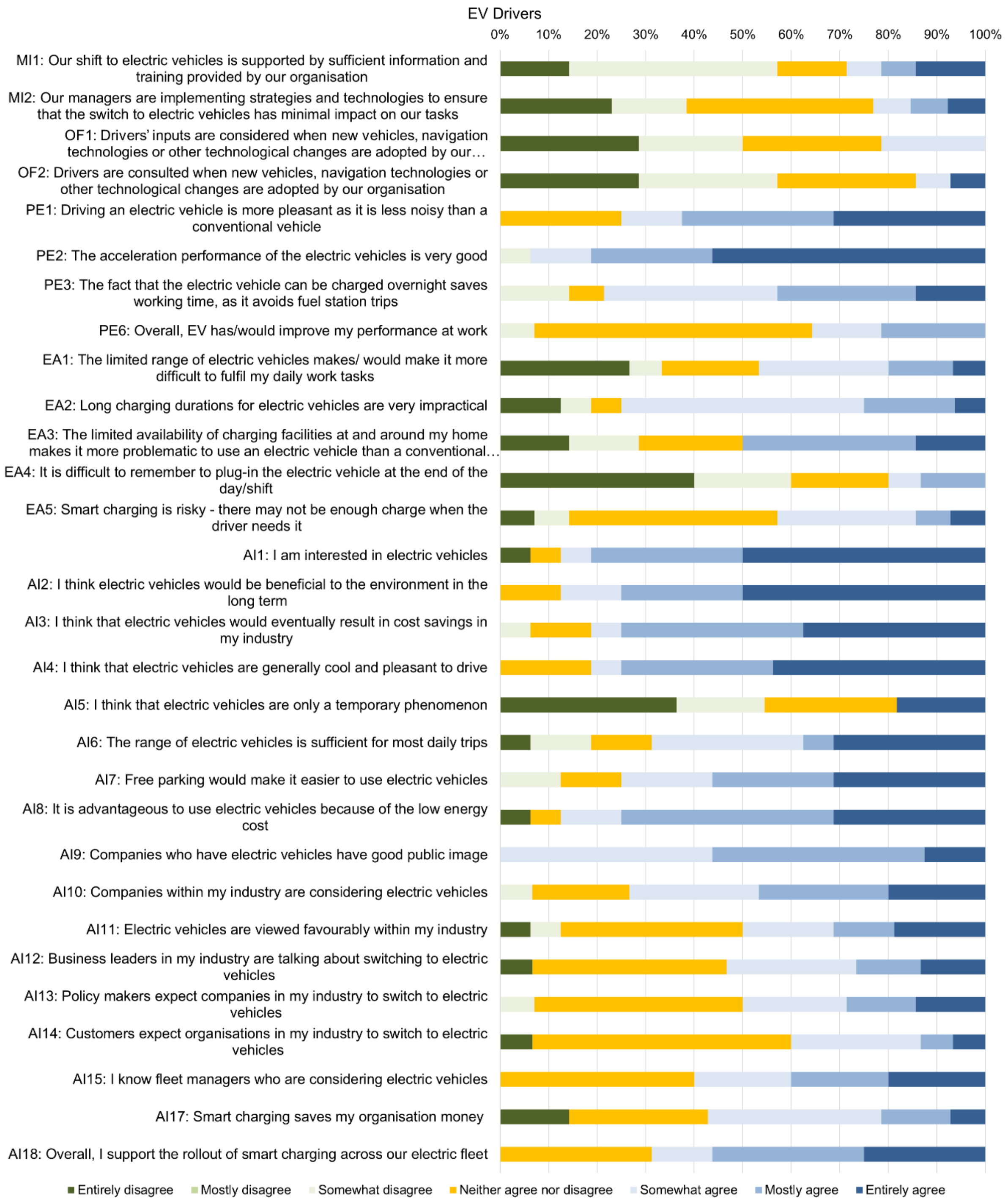


Figure 134 – Frequency analysis - EV drivers



9.5.3 Final comments on the analysis of the Novuna fleet data

The results of the factor analysis are similar to those obtained for Centrica's second survey, and the overall results of the Uber and Royal Mail fleets. This confirms that the results and recommendations can be generalised, given these fleets are similar to Centrica's predominantly home based fleet. The outcomes also present the view of the whole population of drivers; the results of the factor analysis for the non-EV drivers were almost identical to the results of the whole dataset.

To understand better the differences between those with experience driving EVs and those who do not use an EV (at least for work) more responses are required. It is also key to clarify how EVs were distributed within the organisation, because drivers may be biased (e.g. if they were already feeling positive towards electric mobility and therefore asked to be first to try a new EV, while colleagues who were not as interested in the topic opted to keep their ICEV). However, the preliminary insights suggest that more exposure and experience of using an EV leads to higher, positive, rating of EVs.

There appears to be clear differences in typical driving ranges between the constituent fleets, as well as within each fleet, although the small data set makes it difficult to confirm if this would hold for a wider population. Still, it is relevant given the range of the EV used and the allocation process of these vehicles as they are being introduced. Current EV drivers seem to drive less than average, but it is not clear if this is because of their EV or if they have an EV because of the distances they need to travel. By selecting drivers whose driving distance works well with the EV battery size as well as the charging availability, a good match can be found to ensure positive response to the introduction of EVs that does not negatively impact the employees tasks and provides them a comfortable and zero-carbon vehicle which they are happy to drive. Further analysis is required to better understand the relationship between attitudes towards EVs and the driving distance of the respondents.

10 Table of Figures

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