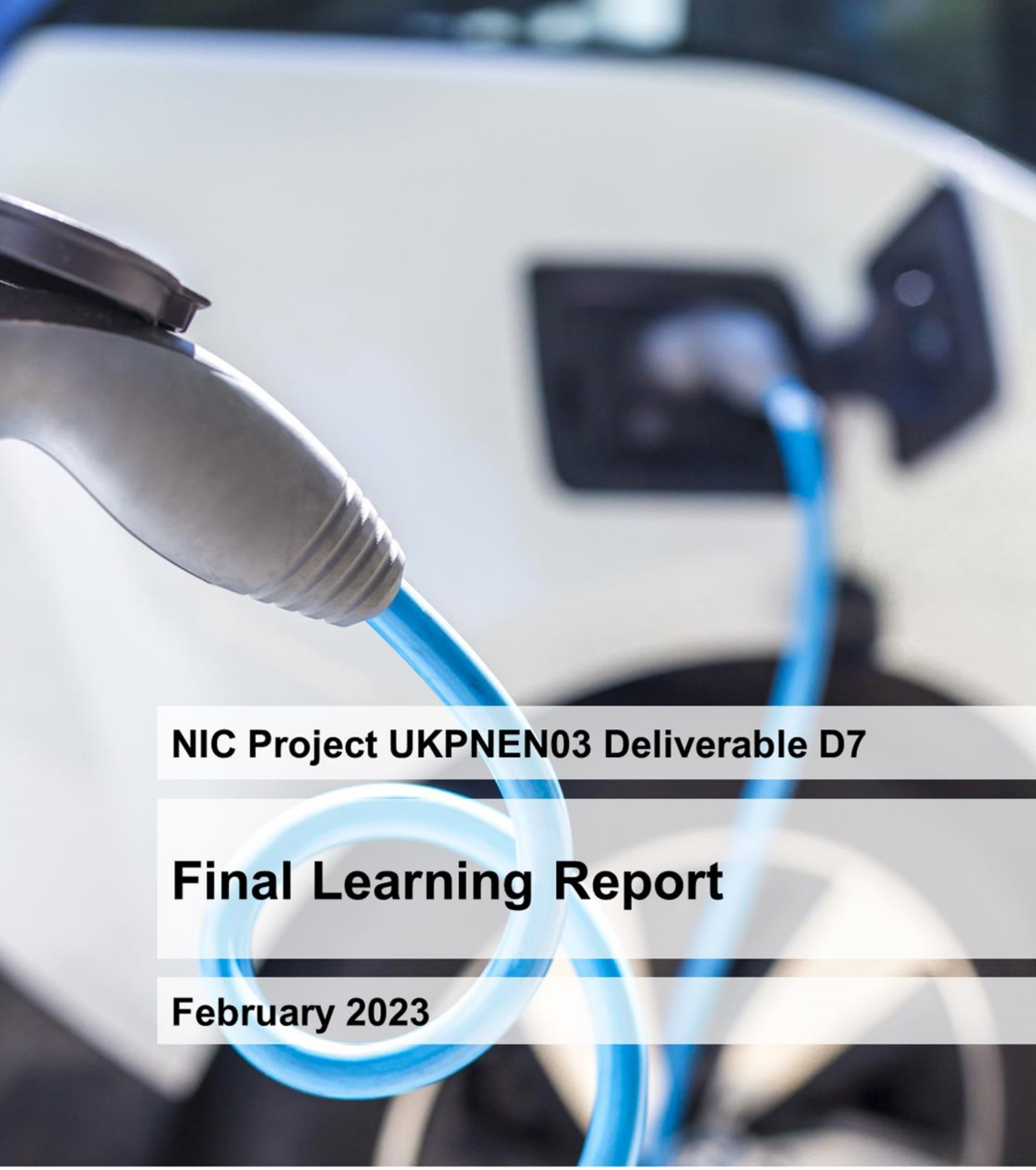


NIC Project UKPNEN03 Deliverable D7

Final Learning Report

February 2023

Optimise Prime

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

Appendices

Table of acronyms & glossary

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

Table 1 – Table of acronyms

Acronym	Full form
ANM	Active Network Management
API	Application Programming Interface
ASC	Authorised Supply Capacity
BM	Balancing Market
CAPEX	Capital Expenditure
CM	Capacity Market
CP	Charge Point
DC	Dynamic Containment
DM	Dynamic Moderation
DNO	Distribution Network Operator
DR	Dynamic Regulation
DSO	Distribution System Operator
DSR	Demand Side Response
EFA	Electricity Forward Agreement
ESO	Electricity System Operator
EV	Electric Vehicle
FFR	Firm Frequency Response
FSP	Full Submission Pro-forma
FU	Flexible Unit

Acronym	Full form
GB	Great Britain
HH	Half-hourly
HV	High Voltage
ICEV	Internal Combustion Engine Vehicle
IT	Information Technology
kW	Kilowatt
kWh	Kilowatt hour
LV	Low Voltage
MW	Megawatt
MWh	Megawatt hour
NIC	Network Innovation Competition
PHV	Private Hire Vehicle
QSR	Quick and Slow Reserve
RFID	Radio-Frequency Identification
RTU	Remote Terminal Unit
SoC	State of Charge
STOR	Short-Term Operating Reserve
TCO	Total Cost of Ownership
UK	United Kingdom
WS	Workstream

Table 2 – Glossary of terms

Term	Definition
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. In Optimise Prime there are three flexibility products: Product A – Firm Forward Option; Product B – Day Ahead; Product C: Intraday.
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.
Smart charging	Charging via a smart charger equipped with two-way communication, enabling charging habits to be adaptive.
Un-managed charging	Charging of an EV at the rate set by the connection until it reaches full charge or is disconnected.

Acknowledgements

Optimise Prime has involved collaboration between an extensive group of project partners and stakeholders. The project team would especially like to thank colleagues, past and present, for their contributions to the project, including:

Hitachi
Lead Author: Ben Kinrade
Daniel Andrade, Bernardo Augusto, Tim Baker, Tania Baron, Nuno Barreto, Andy Baxter, Justin Beasley, Paul Biggin, Max Bird, Michael Blenkinsop, Milosz Bozym, James Bracegirdle, Denzil Buck, Gustavo Carmo, Carla Carvalho, Chelsea Collindridge, Jim Connor, Jim Donaldson, Colm Gallagher, Naveed Gilani, Paulo Gonçalves, Marcin Halupka, Graeme Hodgson, Alex Holland, Paula Jach, Kajetan Jastrebski, Ryan Jenkinson, Don Kamer, David Kingston, Martin Kochman, Carlos Monteiro, Catia Moreira, Priya Nagra, Antonio Nigrelli, Adriano Oliveira, Fernando Oliveira, Joel Paden, Paulo Pires, Inês Pontes, Jonny Restrick, Juvenal Ribeiro, George Roberts, Hugo Seymour, Rakesh Shah, Mark Stubbs, Sam Tadman, Nicole Thompson, Claudio Varano, Tiago Ventinhas, Natalie Walker, Magda Warzecha, Richard Waters, Anna Wieckowska, John Whybrow, Leandro Zolini

UK Power Networks
Florentine Roy, Muhammad Musa, Peter Papasotiriou, Ian Cameron, Chino Atako, Matthew Bates, William Bowen, Carol Choi, Ben Coomber, Sima Davarzani, James Devono, Sam Do, Mark Edwards, Adam Fisher, Joseph Johnson, Chris Knightly, Adam Lakey, Emily Leonard, Ashley Levestam, Tim Manandhar, Paul Measday, Yiu-Shing Pang, Tam Sokari-Briggs, Mark Strains, James Watson

Scottish and Southern Electricity Networks
Frank Clifton, Maciej Fila, Richard Hartshorn

Royal Mail
Stuart Murphy

Centrica
Matthew Harris, Stef Peeters, Rob Simister, Vladimir Vrabel

Uber
Rebecca Jeffery, Alejandro Astiaso

Novuna Vehicle Solutions
Jon Lawes, Katie Patterson, Kate Swift

The project also thanks the suppliers who contributed to the success of Optimise Prime:

CKDelta
Cornwall Insight
EA Technology
Element Energy
Imperial College Consultants
Nortech
Smarter Grid Solutions
Ricardo Energy & Environment – Independent Reviewer

The Optimise Prime team would like to remember our colleague, Joel Paden, who sadly passed away in November 2021. Joel's work was instrumental in the production of the Site Planning Tool and in completing the project's initial data science analysis. Joel had only recently started his career and will be remembered as a talented, cheerful and fun-loving member of the team who is very much missed by the team at Hitachi.

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 and Southern Electricity Networks, Hitachi Europe and Novuna Vehicle Solutions (formerly Hitachi Capital Vehicle Solutions).

The project has gathered data from over 8,000 EVs driven for commercial purposes through three trials. Optimise Prime has also implemented 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 has been aiming 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
- WS3, which uses private hire vehicle (PHV) journey data to model the impact of these vehicles on the distribution network.

All trials concluded at the end of June 2022.

Optimise Prime's outcomes 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 network 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 seventh and final Optimise Prime deliverable, D7, providing a comprehensive overview of lessons learnt from conducting the trials, summarising the data collected, insights gained and detailing the methods trialled throughout the project. Over this time the project has collected and analysed data from a wide range of sources in order to carry out a wide range of experiments. The results of these experiments are presented in this document, together with recommendations for future use of the project methods and data in order to reduce the impact of commercial EV growth on distribution networks.

The key findings, which are discussed in more detail throughout this report, include:

WS1 – Return-to-Home Trials

- Unmanaged, home-based fleets will create concentrated load peaks from 17.00 on weekdays due to the timing of the end of shifts coinciding with network peaks
- Smart charging can be very effective at changing load patterns, however leads to significant 'secondary peaks' overnight. Incentives to drive the smart charging behaviour should be considered to reduce the impact of this behavioural change on the network
- The British Gas home-based fleet was found to be very reliable in the delivery of weekday flexibility services, over a one hour period at specific times, due to its predictable pattern of charging load. Revenue from flexibility, which could amount to around £215 per vehicle per year, can help to improve the total cost of ownership (TCO) for home-based fleets
- Winter EV energy requirements are approximately 30% higher than in the summer
- The proportion of the home-based fleet that relies on public infrastructure has increased throughout the trial. This is because drivers that could charge at home were initially targeted, before moving on to those who needed to use public infrastructure. British Gas estimate that up to 60% of their fleet may need to use public infrastructure once fleet electrification is complete.

WS2 – Depot Trials

- Load profiles are depot specific and can change seasonally, with two main peaks appearing at 14:00 and 19:00, which follow the depot delivery schedules. More rural Royal Mail depots are likely to see their demand peak in the afternoon
- The short and sharp load peaks at some depots limit the duration (up to three hours) and volume of flexibility (up to 25% of the depot's charging capacity) that can be offered. Flexibility products should incentivise participation from fleets that can offer flexibility very reliably and fleets that are less reliable, as well as different volumes of flexibility, to maximise access to controllable load at the best possible price
- Factors impacting reliability of flexibility services include:
  - the **size of the depot –** minor changes at small depots can have a large impact on delivery of flexibility
  - the **CP to EV ratio –** sharing CPs results in higher utilisation, but timing of charge events can be challenging to predict
  - daily **EV mileages –** impacting how long flexibility events can be sustained
  - **operational processes –** such as when EVs are plugged in, the variability of shift patterns and the use of vehicles on different shifts
- Using smart charging to manage load in line with a profiled connection was shown to save some depots up to £95,000 on the cost of connection and up to 12 weeks in the time to connect. While the changes to connection charges announced in the Access and Forward Looking Charges Significant Code Review will lead to customers no longer having to pay for reinforcement of shared assets, these costs were made on extension assets that would still be the responsibility of the customer after the change

- Trials suggest that between seven and 20% of fleet charging costs could be covered by revenue from flexibility services. However, whether this can be achieved depends on the DNO's requirements for flexibility services, the electricity tariff and how this aligns with the depot's charging schedule
- Profiled connections can be successfully implemented, but EV load must be the dominant load in the depot for its control to reliably ensure compliance.

WS3 – Mixed Trials

- Most (77%) demand from PHVs occurred off-shift, with plug-ins peaking at about 20:00, but continuing through the night – later than other fleets would normally plug in
- Future demand from PHVs is likely to shift further towards off-shift charging close to home, as vehicles with larger batteries are able to complete full shifts on one charge, further reducing the proportion of on-shift charging
- It is expected that the rapid growth in the number of Uber EVs will result in a maximum load from off-shift charging in Greater London increasing from an estimated 10 MW in May 2022 to 69 MW by the end of 2025. Over the same period, annual electricity demand from these EVs is expected to reach 497 GWh, compared to 63 GWh used in the year to May 2022. Based on modelling of driver shift times, charging needs and home locations, Optimise Prime estimates that about 33,500 fast CPs may be required to service this demand if drivers opt for overnight fast charging.

Based on the trials, Optimise Prime has developed several recommendations for DNOs regarding the implementation of the methods trialled in the project, including:

Flexibility Services

- The month (or more) ahead product should allow fleets to re-forecast their baseline in the run up to delivery to improve predictability/reliability of outcome
- Pricing incentives should be structured to reward good performance without disincentivising participation by some fleets. A range of products with different performance/reliability thresholds could be implemented to achieve this, with fleets with a higher probability of successful delivery attracting a higher price
- Automation is required in the tender, bidding, dispatch and settlement calculation processes to make provision by smaller assets cost effective
- Baselining establishes a 'normal' level of load against which the delivery of flexibility is judged and rewarded. As EV demand fluctuates, establishing an accurate baseline can be difficult. Tests of several baselining methodologies highlighted the need to use recent data and demonstrated that the most accurate method varied and needs to be chosen based on fleet characteristics.
- Incentives should be structured to prevent the occurrence of secondary peaks which could cause additional problems for the network.

Profiled Connections

- A process to model the expected load flow (such as using UK Power Networks' LV utilisation modelled data), as a proxy for the substation data may be required if no monitoring is available, supplemented with half-hourly data and/or diversity modelling
- Planning systems need to have the capability to assess network loading at a half-hourly granularity, in order to assess the feasibility and benefit of a profiled connection
- The range of contracts should allow for dynamic profiled connections, that can be changed or activated at the request of DNOs to act as flexibility products
- A process to revise profiled connections is needed to allow changes in fleet operations during the life of the connection. A review is likely to be required approximately one month after implementation to ensure the EV load is in line with the forecast. Seasonal updates may also be required, in addition to ad hoc reviews in response to significant changes in fleet or depot operations.
- Integrated monitoring is required to provide the DNO with visibility of breaches, a method of communicating alerts to the provider is also required
- A method to police the profile, either through physical disconnection, economic penalties, or a combination of the two, must be agreed in the contract and implemented.

The structure of this report is as follows:

- **Section 1** introduces this report and provides a brief overview of the project and its trials.
- **Section 2** details the project's key findings from the trials and the main recommendations for the implementation of smart charging and flexibility methodologies. This also considers the benefits and costs to fleets and DNOs resulting from electrification, and considers the infrastructure needed to implement the methods
- **Section 3** describes how the learnings from Optimise Prime are being implemented by UK Power Networks and considers how they can be of use to a range of other stakeholders
- **Section 4** describes how interested stakeholders can make use of the data and systems developed and trialled in Optimise Prime
- **Section 5** presents the final conclusions of the project
- A series of appendices accompany this report, providing greater details of project findings, together with useful documents for stakeholders including the guide to fleet electrification, cost and behavioural analysis and the methodology behind the project's site planning tool.

These findings should prove valuable to any DNO considering how to plan for the future growth of commercial EVs. In addition, vehicle fleet operators planning to implement EV infrastructure and supporting IT systems can learn from the results presented herein and use the project's findings to optimise their EV transition. Although some aspects of the trial design are specific to Optimise Prime and its partners, the principles, objectives and main results are applicable to all DNOs and to vehicle fleets planning a transition to ultra-low emission vehicles.

Table 3 shows the requirements of Deliverable D7, set out in the Project Direction, and where each item can be found within this report.

Table 3 – Deliverable D7 requirements

Deliverable D7: Early learning report on the trials	
Evidence item	**Relevant section of the report**
A report summarising:	
The work undertaken	Described in Section 1
The insights gained from the trials (incl. insights that could feed into Ofgem's network access and charging reform work)	Key insights are summarised in Section 2, while further insights from EV data analysis are presented in Appendix 2, with findings from the methods detailed in Appendix 1
Recommendations on approaches for separating commercial EV load at residential level and likely costs and benefits	Details can be found in section 2.3.1
Models for use of commercial EV flexibility by DNOs	Details can be found in section 2.1.4
Insights from the Method 1 aggregation trials including flexibility contracts to the DNOs	Details of insights can be found in section Appendix 1, with recommendations presented in section 2.1.4
recommendations on business models for fleet operators	Details can be found in Appendices 4 and 6, with recommendations summarised in 2.2
How the trials, the infrastructure and technology should be transitioned after the Project has completed	Details can be found in section 4
How to ensure integration of the Methods with DNO/DSO systems and processes	Details can be found in section 3.1
The methodologies and reference design for the site planning tool developed in Method 2	Details can be found in section 3.2 and Appendix 7
Insights on applicability of Methods to EV stakeholders (incl. other GB DNOs, fleet operators, policy makers)	Details can be found in section 3

Optimise Prime is committed to sharing the project's outcomes as widely as possible. The project has been engaging 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 seventh deliverable of the Network Innovation Competition (NIC) funded Optimise Prime project, gives a comprehensive overview of the findings arising from the Optimise Prime trials.

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 and Southern Electricity Networks, Hitachi Europe and Novuna Vehicle Solutions. The role of each partner is described in Table 4. In total the project has worked with over 70 team members in more than five countries. In addition, it drew on the expertise of numerous companies and individuals providing technology solutions, subject matter expertise and responding to project surveys.

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, helping design and run flexibility trials and 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.

Partner	Description	Project Role
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.
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.

1.1.1 The problem being addressed

The uptake of EVs is expected to cause substantial challenges to electricity networks. This is likely to be initially driven by commercial organisations because commercial fleets are more likely to purchase new vehicles and due to new legislation designed to drive environmental improvements which creates strong economic incentives for businesses to transition to EV.

These two factors are exacerbated by changing transport habits, which are resulting in an increased proportion of vehicles used for commercial purposes on the road. This is due to a rise in online delivery services and new Mobility as a Service offerings such as Uber. Therefore, gaining an understanding of the effects of commercial EVs on the network is essential to ensure that networks will be ready to facilitate the EV rollout expected over the coming years at the lowest cost.

In addition, use of depots results in a higher incidence of clustering, combined with higher mileages, meaning that substantial network reinforcement may be required to support the decarbonisation of commercial vehicles. Without an informed approach to commercial vehicle electrification this could result in potential delays, high costs for fleet operators and for customers.

1.1.2 The Optimise Prime approach

Since early 2020, data from the use of EVs driven for commercial purposes has been gathered and analysed. The EVs were primarily based in London and the South East of England, although some vehicles in the home trial (WS1) were located throughout the UK. By the end of the trials data was being collected from over 8,000 EVs.

Optimise Prime implemented 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 aims 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 is 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 have a much greater impact on the electricity network because of their higher mileages 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 mileages and payloads. The latter is also a factor when commercial EVs are charged at domestic locations.

Two DNO groups (UK Power Networks and Scottish and 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 has allowed 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 has also helped 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 has delivered invaluable insights by using data-driven forecasting tools designed to allow networks proactively to plan upgrades. In addition, this project has created 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 shows customers how smart charging could be used to charge their vehicles within existing connection limits. Where smart charging alone is not possible, the tool provides 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 has sought 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 enables network operators to quantify savings which can be achieved through reinforcement deferral and avoidance while facilitating the transition to low carbon transport. The trial also assessed journey data to understand the charging and associated infrastructure requirements and implications for depot and fleet managers to be able to operate a commercial EV fleet successfully.

To research the answers to the project's key questions, Optimise Prime designed experiments to test with the British Gas, Royal Mail and Uber fleets, principally on the UK Power Networks and Scottish and Southern Electricity Networks distribution networks (the full list of experiments, together with a summary of the findings can be found in Appendix 8). Having built the first of the technology services, Optimise Prime started collecting data from December 2019, enabling the experiments to be executed.

1.2 Purpose and structure of this report

The purpose of this report is to share the final learnings from the Optimise Prime trials and the project's conclusions regarding the viability of the Optimise Prime methods (explained in Table 5). This includes all work done in analysing the data arising from the vehicles and infrastructure involved in the Home (WS1), Depot (WS2) and Mixed (WS3) use cases. This deliverable presents findings that will be of interest to project stakeholders, and help GB DNOs understand how the project methods could be integrated into their business processes in order to accelerate the EV transition and save money for network customers.

This document details the main conclusions and recommendations of Optimise Prime, answering the project's key questions. A series of appendices explore the project's outcomes in greater depth, detailing the experiments the results of trialling the project's methods, insights from analysing vehicle data, results from economic and behavioural analysis.

1.3 Trials context

The main elements of the infrastructure and technology solution are set out in the FSP and are designed to support the three trials and two project methods (Table 5, below). The trials align with the fleets of Optimise Prime's three fleet partners, representing home, depot and mixed charging as shown in described below.

WS1 – At-home Trial

WS1 was the home charging trial, focused on studying the charging behaviour and flexibility provision of a fleet where commercial EVs return to drivers' homes to charge. The trial collected data from the vehicles and chargers and tested the provision of flexibility services through the optimisation of vehicle charging by an aggregator, which has been analysed to model impact on the distribution network. In Optimise Prime, the trial involves Centrica's British Gas maintenance fleet of electric light commercial vehicles.

The aim of this trial was to quantify the current and potential impact of home-charged light commercial vehicles on the distribution network. The trial also tests solutions that may reduce costs for network customers by allowing upgrades to be deferred through the use of EV flexibility services.

WS2 – Depot Trial

WS2 was the depot charging trial, focused on controlling sites where vehicles charge simultaneously. In Optimise Prime, battery-electric vans at nine Royal Mail depots, in and around London, were smart-charged in order to comply with profiled connections, requests for flexibility provision and to simulate cost minimisation by using cheaper electricity tariff times.

WS3 – Mixed Trial

WS3 was the mixed trial, involving trip data from Uber PHVs operating within Greater London. This trial focused on the analysis of data that is collected from Uber's platform and did not involve the implementation of methods or physical infrastructure. The data from Uber was combined with CP location data and substation loading data to predict load from PHVs on the network now and in the future.

Two methods were tested through the trials. They are summarised in Table 5, below.

Table 5 – 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.

1.4 Trials Overview

The Optimise Prime trials were 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 was broken down into a series of objectives, listed in Table 6, based on the project's core questions. The table shows which of the objectives is relevant to each trial. The objectives are broken down into sub-objectives, and experiments. The experiments were carried out in order to fulfil the objectives and answer the project's key questions.

Table 6 – 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	✓	✓	✓
2. Assess the effects of profiled connections on fleet EV transition		✓	
3. Assess smart electrification strategies	✓	✓	
4. Assess the ability of EV fleets to provide flexibility services to the DNO	✓	✓	✓
5. Evaluate operational limitations to commercial fleet electrification	✓	✓	

The experiments were designed to be iterative and were run multiple times during the preliminary implementation phase, allowing for lessons to be learned from the first runs and applied to the execution approach before the formal trials began. As the trials progressed, the experiments were updated based upon learnings from the trials. Learnings from these experiments are presented in this report, with the full breakdown of findings from each experiment given in Appendix 8.

Optimise Prime undertook the world's largest commercial EV trial, involving 8,138 EVs, more than double the project's original aim. Some key facts about the trials can be found in Table 7.

Table 7 – Key figures from the project

Metric	WS1 – Home	WS2 – Depot	WS3 – Mixed
EVs	1,083	342	6,713
Shifts/active days	175,838	136,841	1,711,587
Average miles driven/ day	50 miles/day	16 miles/day	77 miles/day

In addition to directly trialling technology solutions, the project completed surveys of 3,292 drivers and 29 management representatives, across ten companies, to understand opinions on EVs, how drivers perceived their company's approach to electrification; perceptions on public and private charging infrastructure and the performance of EVs. Conclusions on potential barriers to EV adoption and recommendations are made on how other fleets could improve their transition to EVs. These are reflected in the fleet electrification guide, found in Appendix 6, as an aid to help other fleets electrify based on the project's findings.

The project built a Site Planning Tool, hosted by UK Power Networks: https://www.ukpowernetworks.co.uk/optimise-prime/site-planning-tool-introduction

The tool enables fleets to assess their electrification needs before starting discussions with the DNOs. This tool highlights the benefits of smart charging and supports the profiled connection application process.

Optimise Prime deployed an optimisation engine developed by Hitachi to manage the Royal Mail CPs and built forecasting models to participate in flexibility events, trial profiled connections and charge according to different electricity costs. British Gas' vehicles, located at drivers' homes, were also aggregated to provide flexibility services. The project assessed the operational characteristics of the three fleets, their EV uptake forecasts; their trips and schedules; demand for public charging and the cost of EVs when compared with their existing diesel and petrol fleets.

2 Key findings and recommendations for implementation of project learnings and methods

This section sets out to provide answers the three key questions set out in Section 1:

- How do we quantify and minimise the network impact of commercial EVs?
- What is the value proposition for smart solutions for EV fleets and PHV operators?
- What infrastructure (network, charging and IT) is needed to enable the EV transition?

The answers highlight the key findings from the Optimise Prime project. Appendices 1 and 2 accompany this section, providing further details of the trials of the methods and observations and modelling of fleet activity, respectively.

The project also provided an opportunity for a third-party organisation to conduct analysis on the data collected by the project in order to develop additional insights. A summary of the outcomes of this work, completed by CKDelta, can be found in Appendix 3.

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

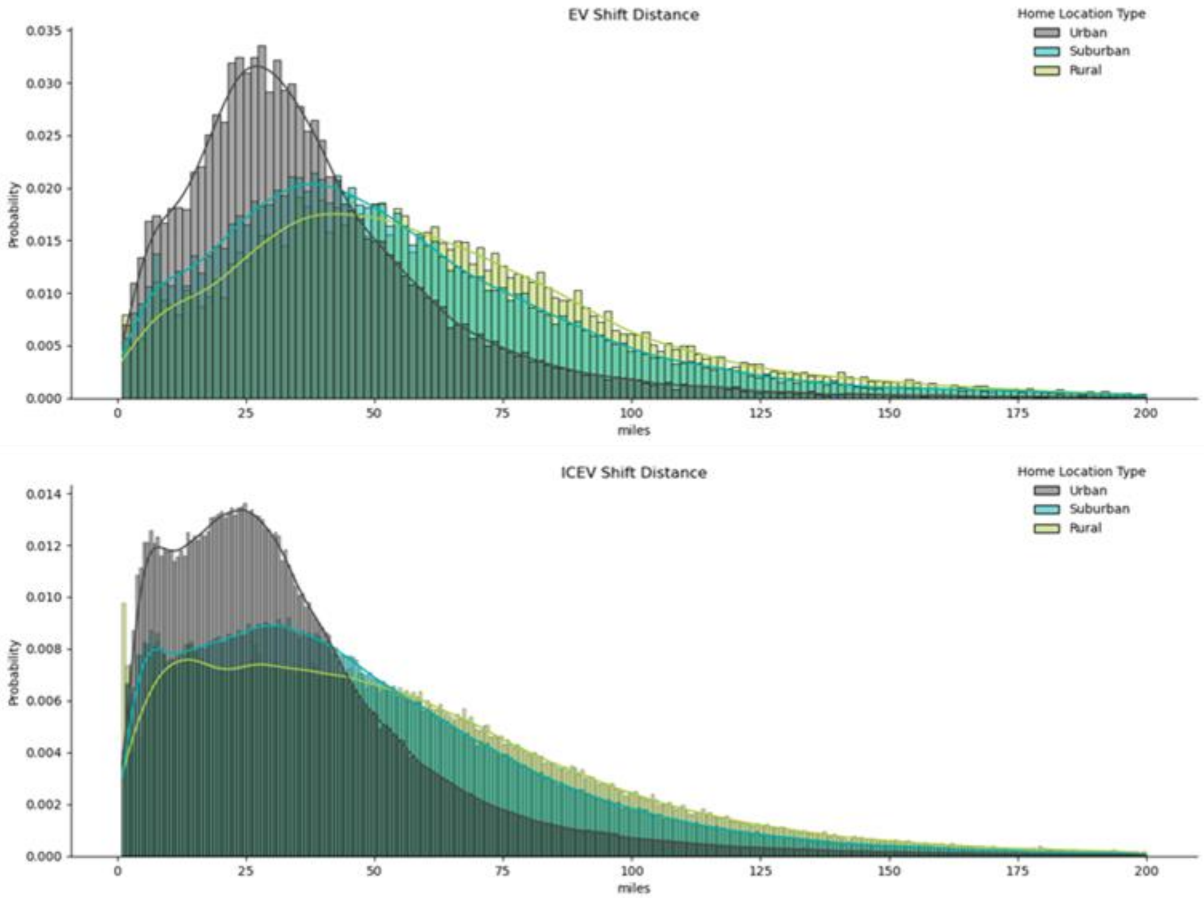
2.1.1 Operational analysis of shift patterns and un-managed load profiles

Establishing factors such as demand peaks, shift patterns, seasonality and vehicle capabilities has allowed the project to understand the current charging patterns of the trial fleets.

The average mileage for the three fleets was well within the range of the EV models selected by the project partners, proving that the electrification of these fleets was feasible for the routes considered. At Royal Mail, few vehicles exceeded 30 miles per day; British Gas' journeys were more varied, with some daily shifts in excess of 100 miles. However, EVs have been able to complete these distances throughout the trials – Figure 1 shows the range of shift distances seen throughout the trials at British Gas.

The diesel fleet schedules for both Royal Mail and British Gas were found to be an accurate proxy for the EV fleet when forecasting electricity demand. The Uber electricity demand was derived by modelling trip patterns and estimating when drivers needed to charge (based on vehicle range) and were able to charge (based on gaps in their schedule and CP locations) and probability models on when they did charge. Feedback from driver surveys and discussions with Uber were also used to inform and validate the assumptions made in this modelling.

Figure 1 – Shift distance comparison of British Gas EVs and ICEVs



The key conclusions from studying operational data across all three fleets are:

Existing EV models can cover the typical daily range requirements of all three fleets
Adoption of EVs by commercial fleets can be expected to proceed as fast as supply of vehicles allows, and where there is a business case

Unmanaged, the fleets will create concentrated load peaks defined by the timing of shifts
The majority of British Gas and Royal Mail vehicles operate during business hours. It is likely that many other fleets will operate in a similar way. This increases the importance of smart charging control to avoid a large peak in power for charging when commercial drivers return from their daily operations and plug in their vehicle between the hours of 17:00 and 20:00. The British Gas peak was around 17.00; the Royal Mail peaks were at 14.00 and 19.00, reflecting different depots' schedules. Uber on-shift plug-ins peaks at 14:00 and 19:00, while off-shift plug-ins peak at 19:00 and 23:00, resulting in a load peak in the early hours of the morning.

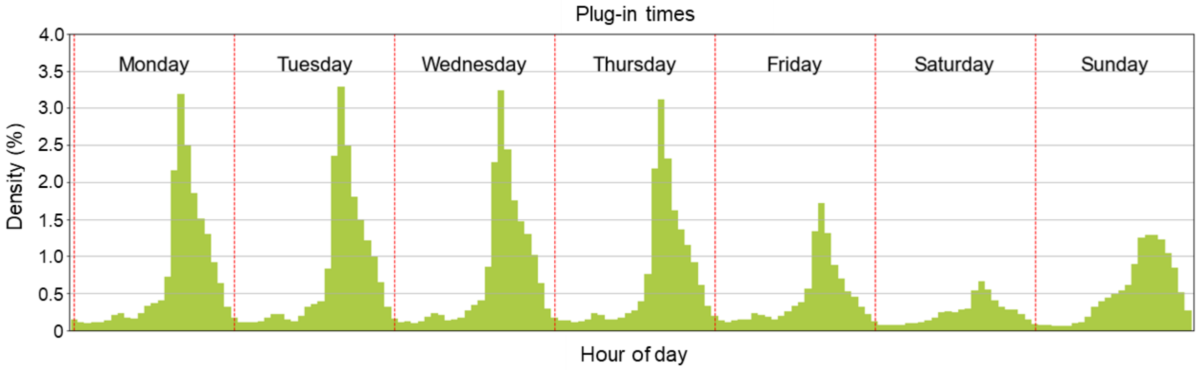
The following sections discuss the findings from the three fleets in more detail:

2.1.1.1 Home based fleet

British Gas EVs drove an average of 49.7 miles per day (compared with 43.9 miles per day for the diesel fleet, the difference may partially be due to the prioritisation by British Gas of EVs on CP install jobs, which could involve longer travel time) requiring an average of 70 kWh per EV per week. The vehicles followed three main shift patterns: a standard working day, a longer day and a reactive shift responding to callouts.

The standard shift made up the majority (54% of EV shifts), and as a result most British Gas vans consistently plugged in around 17:00 from Mondays to Thursdays. It is notable that charging volumes on Fridays were significantly lower, as shown in Figure 2, with some drivers choosing to charge over the weekend instead. Weekend demand was lower and less predictable as it did not follow the pattern of shifts.

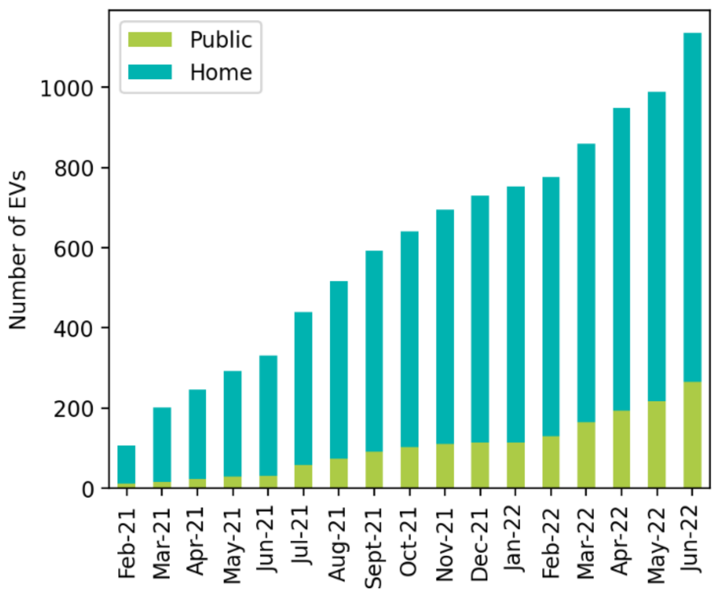
Figure 2 – British Gas plug in volume per day



Current home-based fleets will need significant amounts of public infrastructure in addition to home charging

British Gas currently charge 74.7% of their EVs fully at drivers' homes (down from 89.5% at the start of the project, as shown in Figure 3). This is expected to drop further to around 40% by 2030 as EV rollout moves on to drivers who are unable to install a CP at home (e.g. because of capacity restrictions, or physical limitations to install cabling or a CP at a garage or driveway). The resultant increasing reliance on the public charging network may require collaboration with CPOs, at dedicated hubs. This is an important consideration for other fleets which usually base vehicles at home, and for network operators considering where the demand on the distribution network may appear.

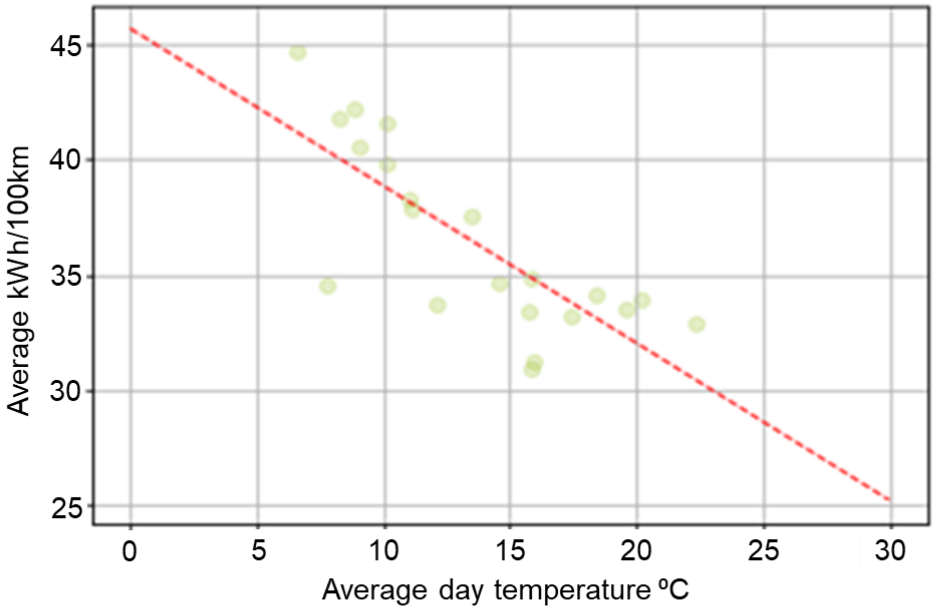
Figure 3 – Growth of British Gas EVs using public charging during the trials



Winter EV energy requirements are 30% higher than in the summer

The British Gas EV fleet requires around 30% more energy in the winter months compared to the summer. This is due to a combination of the reduced energy efficiency of EVs in cold weather (potentially caused by increased use of heating or other factors), and the seasonal nature of the British Gas workload resulting in more shifts and longer journeys. Taking EV efficiency alone, range was found to decrease by 7% for every 10ºC decrease in average temperature, as shown in Figure 4.

Figure 4 – Average efficiency of British Gas vans vs average temperature



Around 34% of British Gas' diesel fleet is urban, 44% sub-urban and 22% in rural locations. While there are differences in the mileage and route types based on location, as shown in Figure 1, vehicles within each location type were found to have similar demand profiles.

Further analysis of the operations of the home-based fleet can be found in Appendix 2.

2.1.1.2 Depot based fleet

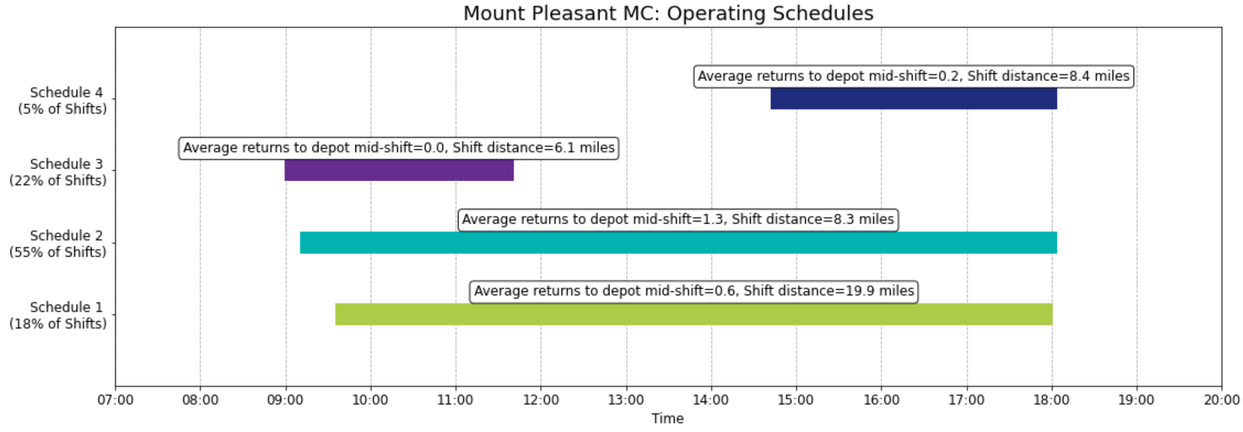
The Royal Mail vans involved in the trial drove an average of 16 miles per day requiring an average of 6.9 kWh per EV each day. This compares with a national average of 23.6 miles for the existing fleet. This difference is due to the urban nature of the trial depots, which are primarily located in London.

Royal Mail has two main shift patterns, which are depot specific:

- Shifts where the vehicle returns in the early afternoon
- All day shifts, ending in the early evening

Vehicles on all day shifts often return to the depot in the middle of the day, sometimes long enough to charge. Some depots have a mixture of both shift patterns, such as Mount Pleasant, as shown in Figure 5, while some predominantly have morning shifts.

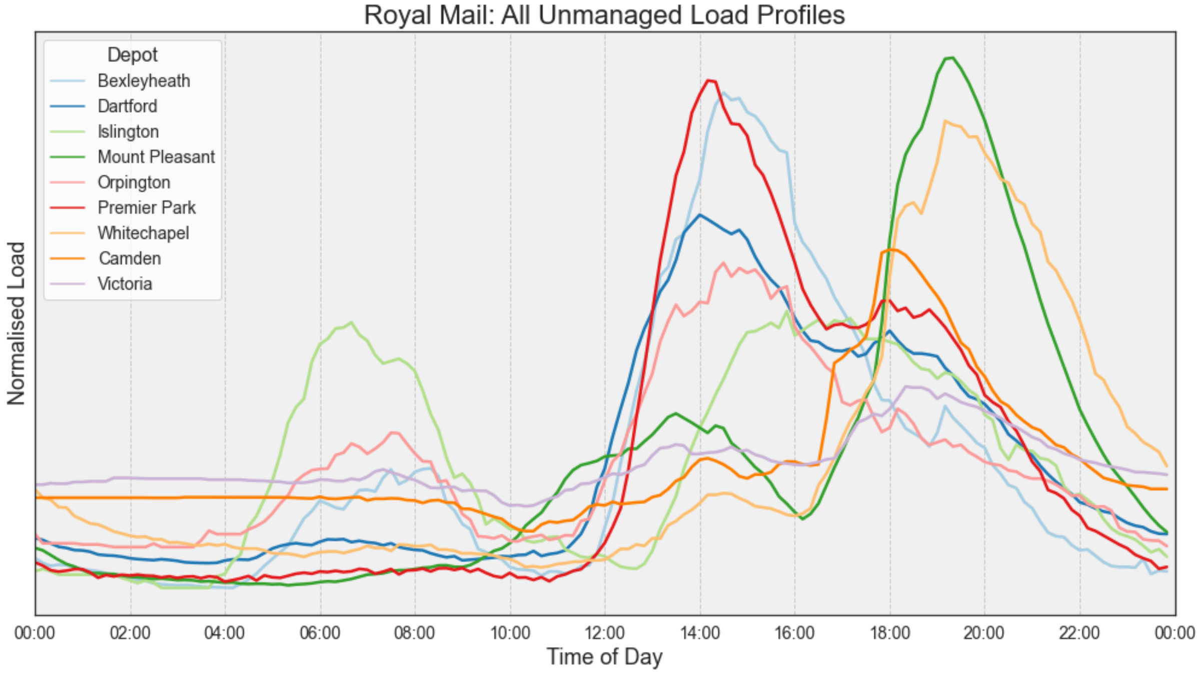
Figure 5 – Vehicle schedules at Mount Pleasant Mail Centre



Load profiles are depot specific and can change seasonally

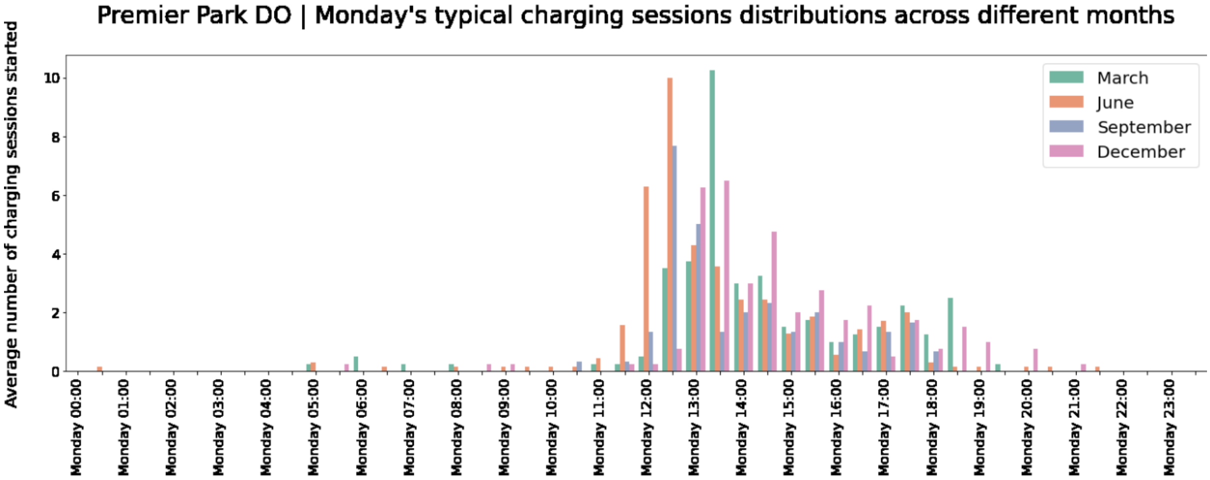
This results in the Royal Mail fleet causing un-managed charging peaks on the network around 14:00 and 19:00 at different depots. The difference in load shape across the nine depots studied can be seen in Figure 6. The load shape is generally driven by the end time of shifts, but some depots have different operational practices that can lead to demand at other times (e.g. where there is more than one EV to a CP), such as early in the morning.

Figure 6 – Royal Mail unmanaged load profiles by depot, normalised



The peaks happen slightly earlier in the spring and summer when delivery volumes are lower and rounds are completed more quickly. Figure 7 shows how at one depot, plug in times in June were around one to two hours earlier than in December, which has consequence for forecasting flexibility and planning profiled connections.

Figure 7 – Seasonal variation in plug-in times at Premier Park depot



Plug-in times cannot always be accurately predicted from vehicle return times and electrical load from EVs is generally significantly lower than the depot capacity

Plug in times were harder to predict accurately for Royal Mail because when the EV returns to the depot, it is not immediately plugged in, while loading and un-loading of post takes place.

Additionally, some depots have a 1:1 CP to EV ratio, while others have up to three EVs per CP. This, combined with low mileages, means that EVs are not necessarily charged every day. The utilisation of CPs reflects this and varies greatly – for a large depot, like Mount Pleasant in Central London, between 20% and 50% of the potential 505kW load (if all of the CPs were in use simultaneously, charging the fastest charging vehicles) has been observed during weekday peak hours.

Depot fleets also have higher winter energy requirements

Overall, the Royal Mail EVs required approximately 26% more energy to complete their tasks over winter because of higher parcel volumes, longer schedules and impacts of colder weather impacting the efficiency of vehicles (including greater use of heating). The variability across seasons is dependent on the operating parameters of each depot. For example, in the Dartford depot, 66% more energy is required in the winter months (December to March) compared to the summer months. The Camden depot required just 6% more energy in winter which shows the varying impacts seasonality can have on a depot's charging requirements. This variability makes it difficult to forecast accurately depot specific demand without a data set covering at least a full year.

Forecasting must accommodate both shift and weather pattern changes, both of which have a larger impact than the initial hypothesis that relatively fixed Royal Mail schedules would result in stable demand profiles.

The operational and load characteristics of depot charged EVs are explored in more detail in Appendix 2.

2.1.1.3 Mixed charging

Uber PHVs use a mixed charging model: both charging at or near home while the app is off (off-shift) and charging at public chargers between journeys (on-shift). Uber off-shift demand is highest from around 20:00, continuing until after midnight, where the peak load on the distribution network occurs. Uber on-shift demand has two separate peaks at 15:00 and 20:00.

On average, Uber PHVs drove 77 miles per shift on Uber trips, requiring an average of 140 kWh per EV/week (note, this does not include personal journeys when the app may have been switched off, or journeys booked via alternate platforms).

The average battery size increased by 42% over the three years that the project has been gathering data as more capable vehicles joined the platform. This trend has an impact on the future forecasting as EVs may require less frequent higher power charging sessions and more demand to off-shift, at home charging, over time.

The electric PHV fleet's trip demand was found to be stable, regardless of the weather, although there is likely to be some seasonal impact on power demand, as seen in the other trials, due to the lower efficiency of EVs in colder weather.

Around 77% of Uber EVs charge off-shift – i.e., when the Uber app is off. Off-shift charging uses a combination of off-street, at home charging and public charging. The boroughs of Barnet, Croydon, Ealing, Hounslow and Lambeth see the most off-shift charging today. As more drivers adopt EVs this demand is expected to shift, reflecting where Uber drivers live – Tower Hamlets and Newham are expected to see the most off-shift charging events by 2025, this future forecast is covered in more detail in Section 2.1.2.2.

The on-shift demand appeared throughout the day at in Central London and at Heathrow Airport and more sporadically elsewhere in the city. Uber drivers sometimes drove more than 2km from their ideal charging location to a charge point while on-shift – suggesting that CPs are not located in the immediate areas of demand. The most heavily used charge points were assessed to be up to five times over-utilised at peak times if drivers were to always use the most convenient location.

More details about the operational analysis of PHVs can be found in Appendix 2.

2.1.2 Forecasting future EV demand and network impacts

In order to estimate future demand on the distribution network, Optimise Prime has forecasted the growth in electricity demand from the project's EV fleets, given their transition plans, as well as the wider impact of commercial EV charging on network upgrades throughout the UK Power Networks licence areas.

The EVs involved in the trial in June 2022 represented approximately 1.3% of Royal Mail's national fleet (342 EVs), 10% of the British Gas fleet (1,083 EVs) and 17% of the Uber PHVs in operation in Greater London (6,713 EVs).

2.1.2.1 Growth of the Home and Depot fleets

Several uptake forecasts were modelled for the fleets, with a high uptake scenario representing their planned transition and more conservative scenarios showing potential uptake if there are supply issues or other constraints.

It is estimated, in the high uptake scenario that by 2025 around 70% of the British Gas and Royal Mail fleets and 100% of the Uber's London PHVs will be electric. All three partners aim to fully electrify their fleets by 2030, provided that sufficient vehicles and infrastructure are available. By extrapolating the demand for charging, in an unmanaged scenario it is estimated that British Gas' national fleet will create a peak demand of nearly 12MW once fully electrified, as shown in Figure 8, while the Royal Mail fleet will create a 50MW peak, as shown in Figure 9.

It is notable that the Royal Mail peak is much earlier in the day, at around 13:00-14:00 due to the shifts at more rural delivery offices ending earlier. This could make on-site solar generation useful to reduce peak load at these depots. The potential for solar power to offset electrical load at Royal Mail depots is discussed further in Appendix 2.

Figure 8 – British Gas fleet load, UK wide – 2030

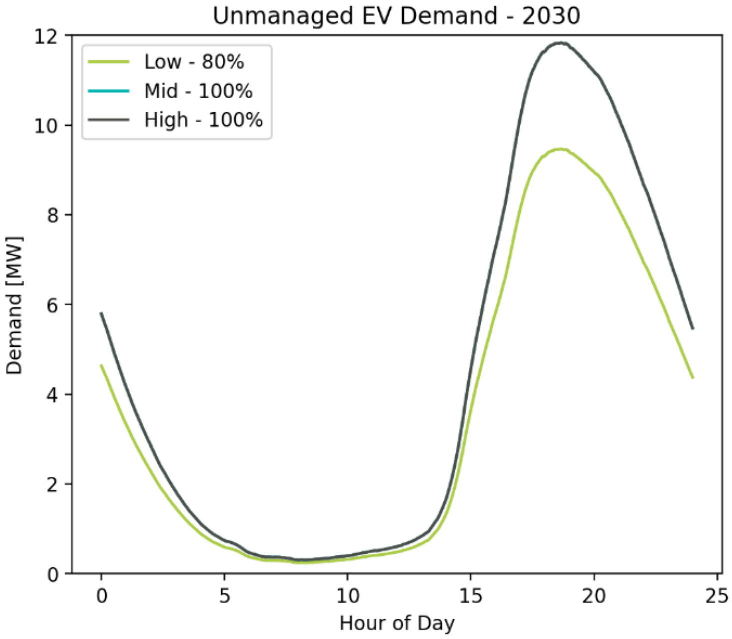
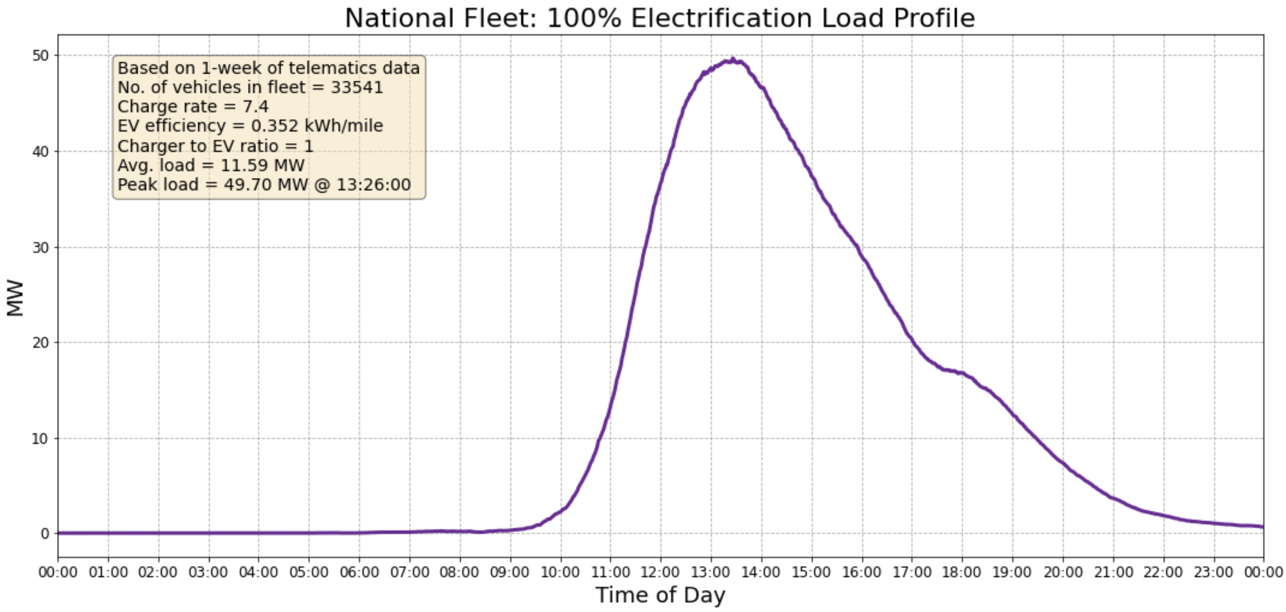


Figure 9 – Load from full electrification of Royal Mail national fleet

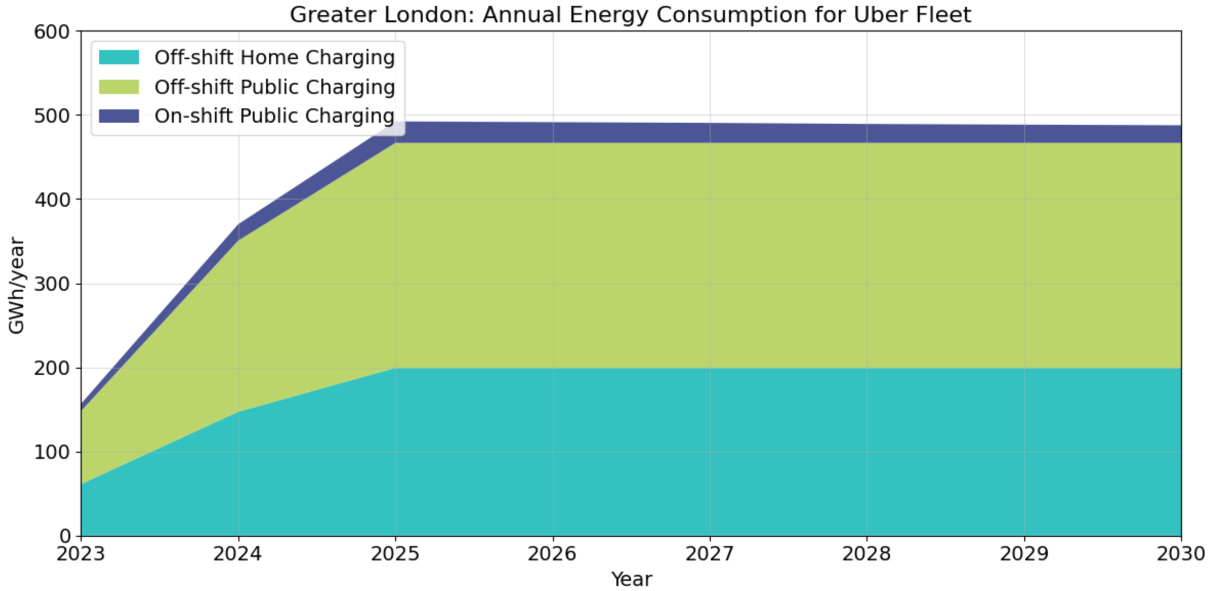


2.1.2.2 Mixed trials

With the data from Uber PHVs, a detailed analysis was performed of future demand for charging, including the number and location of public CPs and the overall load on the network.

The demand from the fleet of 6,775 EVs in use at the end of the trials was extrapolated based on Uber's electrification forecast, which expects that all PHVs on the platform to be EVs by the end of 2025. This was then overlaid against UK Power Networks' substation capacity data, allowing the team to analyse the locations and quantities of CPs that will be required to service demand, and what capacity the network will require to serve the CPs. Total demand from Uber PHVs is expected to reach 497 GWh per year by 2025, as shown in Figure 10.

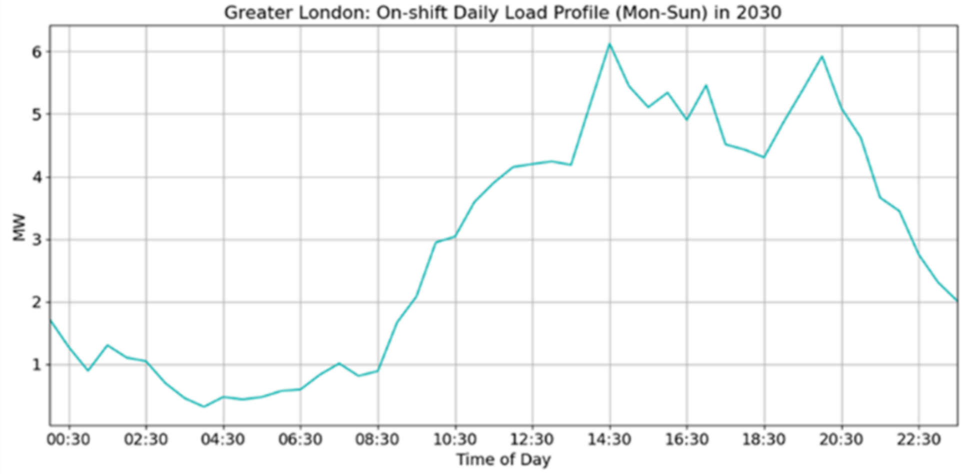
Figure 10 – Forecast annual energy consumption of Uber PHVs in Greater London

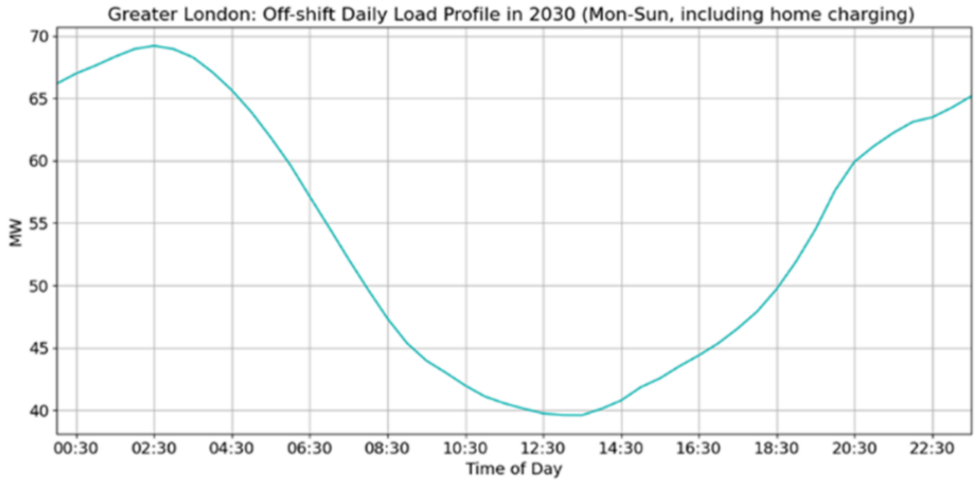


Load from PHVs is likely to primarily occur outside of the early evening peak load time on the distribution network

Charging of Uber EVs on public charging infrastructure is expected to create a maximum load of 6MW from on-shift charging and 69MW from off-shift charging by 2030, as shown in Figure 11. While peak load from on-shift charging will primarily be in the afternoon and evening, it is relatively small compared to the load from off-shift charging, which peaks overnight between at around 02:30.

Figure 11 – Diurnal view of Uber load on-shift (above) vs off-shift (below)





In order to translate this load growth into requirements for public CPs, two scenarios were considered. In scenario one off-shift charging primarily uses fast (7kW) CPs and in scenario 2 off-shift charging primarily uses ultra-rapid CPs. In both cases, on-shift charging uses ultra-rapid CPs where possible in order to minimise the time spent charging during the shift.

Growth in PHV demand is forecast to require a substantial investment in new CP infrastructure throughout Greater London

Overall, in London there are currently 523 rapid and 293 ultra-rapid CPs. By 2030, it is estimated that an additional 74 rapid and 173 ultra-rapid CPs will be required, primarily to meet on-shift demand, and an additional 33,539 fast CPs will be required to meet off-shift demand. In the scenario where ultra-rapid CPs are preferred by all drivers, a total of 2,267 ultra-rapid chargers will be needed. The analysis primarily takes into account Uber's charging requirement, but considers that the utilisation of each CP by Uber drivers is likely to be in the range of 7.5-15% – allowing other drivers to use the CPs. It should however be noted that this analysis only quantifies the requirement for CPs that will be used by Uber PHVs – other EV users will also have demands for additional CP infrastructure, and further research may be needed to identify how much infrastructure will be needed to accommodate them and the resultant impact on network capacity.

Overall, there is generally sufficient capacity on the network to meet the future charging needs of Uber PHVs. Even in the top five boroughs for CP growth, the additional load will be equivalent to between 5.3% and 7.7% of available headroom on secondary substations. The ability of individual substations to take additional load does vary, however. Limitations on charging are likely to be the result of other considerations, such as space, physical ability to connect in specific locations and ability to connect multiple chargers in the same location.

In order consider cost to the charge point operator of installing the necessary CPs, the UK Power Networks connections team carried out a feasibility study on 30 potential sites in the borough of Newham for on street fast CPs serving off-shift demand and 20 sites, mainly in Central London, for rapid/ultra-rapid CPs to serve on-shift demand.

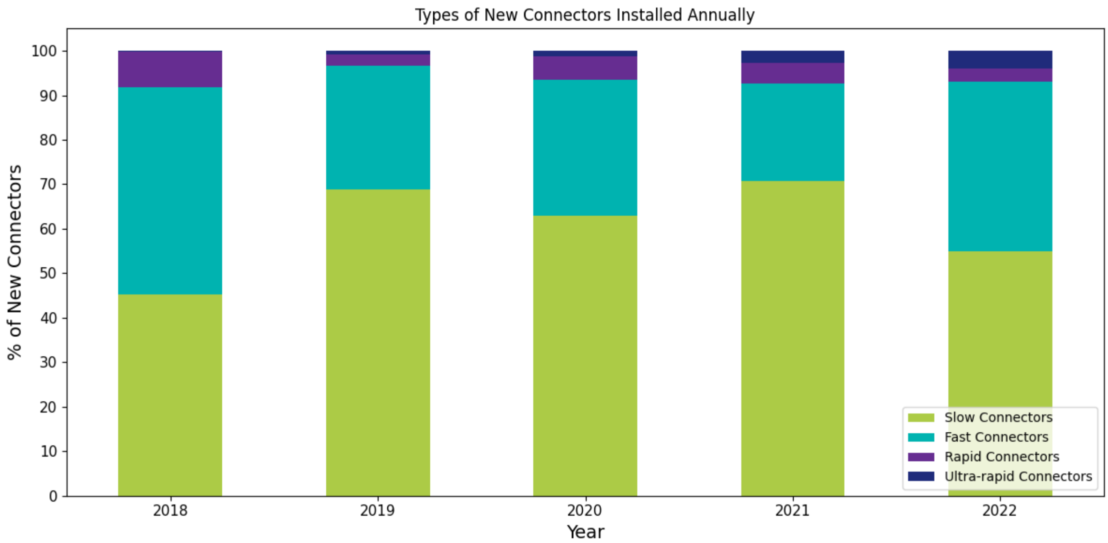
Of the 30 locations in Newham, 27 were located on the same side of the road as a low voltage (LV) main and would require minimal work by the DNO and a connection cost of approximately £2,500 per site, accommodating up to three 7.4kW CPs. The remaining three potentially required additional cables to be installed increasing costs to up to £10,000.

Of the 20 sites selected for on-shift CPs, seven were capable of supplying an ultra-rapid CP from existing transformers. Ten could only support rapid CPs (although sometimes in multiple if split among different points of connection. At the remaining locations a suitable site for a CP could not be found. DNO costs generally ranged from £10,000 to £30,000 per location. This highlights the potential additional cost of installing ultra-rapid infrastructure in areas, such as Central London, that in aggregate have sufficient capacity or if a provider were to choose to co-locate multiple rapid CPs in a hub.

The changing mix of CP types being installed will have an impact on connection planning and costs for charge point operators

Between 2019 and 2022, the proportion of rapid chargers (50 kW), which are typically connected at LV, has decreased from 14% to 12.5% in the Greater London area, while the proportion of ultra-rapids (150kW), typically connected at High Voltage (HV), has increased from 2.8% to 5.8%, as shown in Figure 12.

Figure 12 – Types of new connectors installed annually in Greater London – 2018 to date

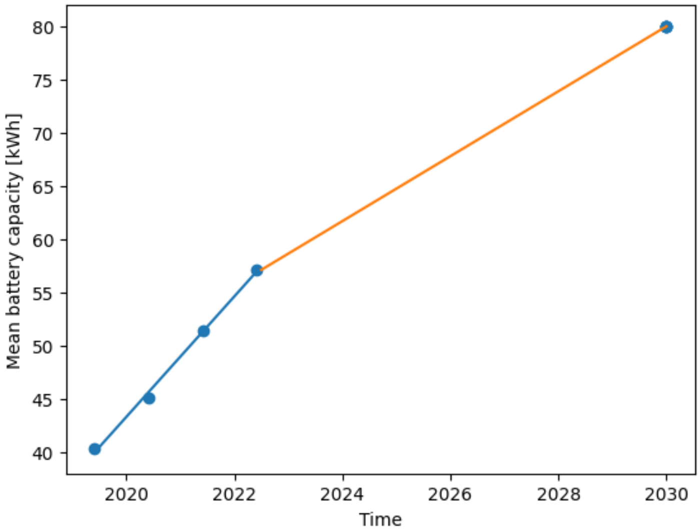


This has an impact on the network planning, cost and timeframes to connect, especially if there is a requirement for multiple CPs to be installed in a single location. As noted above, while up to three 50kW rapid CPs or one ultra-rapid can often be accommodated, this is not always the case, and installation of multiple ultra-rapid CPs will almost always require a new dedicated substation to be installed – requiring sufficient space, costing upwards of £100,000 and taking significantly longer to install.

The requirement for public charging is likely to shift, as longer vehicle ranges will mean less on-shift charging is required

At present the project's modelling suggests that around 27% of charge events happen on-shift. By 2030 it is expected that this will reduce to 16% of all charging events, and 5% of energy delivered. This change in the modelling is primarily due to the increasing size of EV batteries allowing more vehicles to complete a full day of work without needing to charge. The mean battery capacity has increased by 42% since the start of the trials, as shown in Figure 13. It is expected has been forecast that this growth will continue, though at a slower pace, over coming years, to reach 80kWh, the IEA's predicted average battery size in 2030.

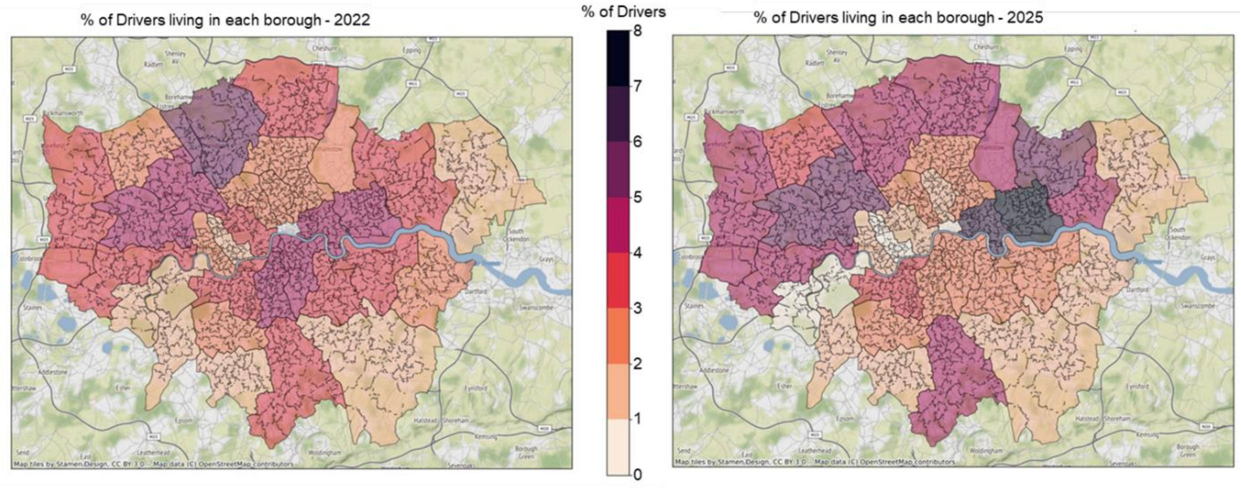
Figure 13 – Growth in mean capacity of PHV batteries



Over time the location of demand will shift, the home locations of EV first movers are not representative of the wider fleet

In addition to increased off-shift demand close to drivers' homes, it is expected that the location of demand will shift in the future, as EV use shifts from PHV drivers who choose to be an early adopter (who are more likely to have home charging) to all drivers in London. Figure 14 shows how the concentration of Uber EV drivers is expected to change between 2022 and 2025 as more drivers electrify.

Figure 14 – % of Uber EV drivers living in each London Borough, 2022 (left) and 2025 (right)



The full analysis of future demand from Uber PHVs can be found in Appendix 2 section 3.

2.1.2.3 Network impact

Optimise Prime collaborated with Element Energy, who support UK Power Networks with their Strategic Forecasting System (SFS), to model network impacts based on trial data.

The first phase of this work, detailed in Deliverable D5, used preliminary EV charging behavioural datasets for Royal Mail and British Gas fleet vans and Uber PHVs to create a first order estimate of the impacts of EVs, and of smart charging on future network load and reinforcement requirement.

In the second phase, modifications were made to the SFS to provide more granular modelling of fleet types (specifically, allowing the Royal Mail and British Gas charging profiles to be applied to specific types of vans). Additional data from the trials was also entered to compare the impact of different charging regimes:

- Unmanaged charging
- Time-of-use smart charging
- Provision of flexibility
- Profiled connections.

These charging regimes were entered into the SFS in the form of plug-in time profiles derived from recorded:

- Charging times
- Daily mileage
- Charging speeds
- Charging frequency
- Charging location types.

Where information was not gathered in the trials (for example a smart charging profile for PHVs), the default SFS data was used.

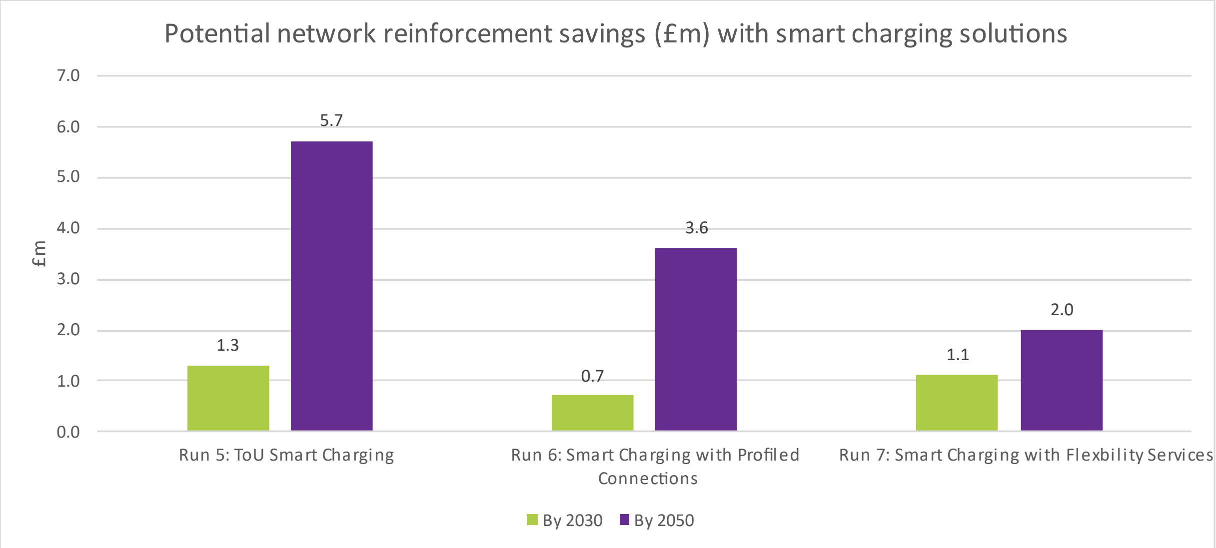
This analysis applied the Optimise Prime results to all vans and PHVs in the UK Power Networks footprint to understand how these vehicles are likely to contribute to peak load at substations across UK Power Networks' area up to 2050. This impact was quantified in terms of required investment to replace network assets. Seven scenarios were run, with different combinations of the charging regimes, in order to identify the impact of each method on network investment. These scenarios model a case where all fleets would have the exact same characteristics as the Royal Mail, British Gas and Uber fleets. Many fleets will have broadly similar characteristics and therefore would also contribute to peak demand. However, it is worth noting that each fleet will have unique characteristics related to business-specific operational schedules and EV models, most importantly in terms of:

- Mileage
- Load peak time
- Vehicle efficiency.

These characteristics are likely to impact the precise load that each fleet will add to the network.

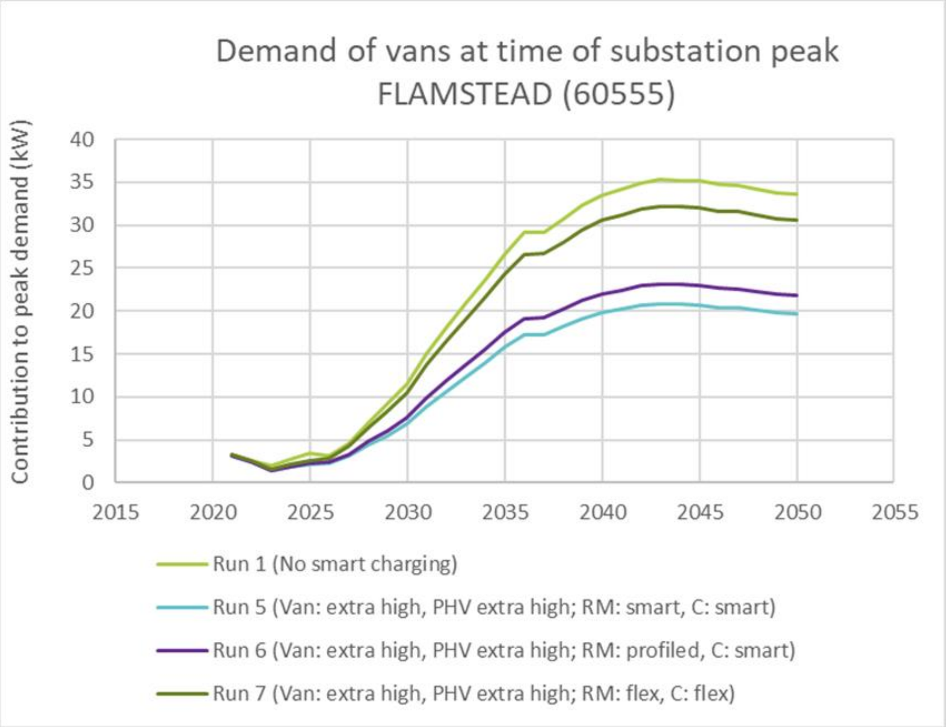
Modelling suggests that smart charging by fleets and PHVs, which could be incentivised with time of use (ToU) tariffs, may result in the largest cost savings by 2050 as illustrated in Figure 15 below. These savings could be up to £5.7m in avoided network asset reinforcement, compared to an unmanaged charging scenario, under the conditions of the Optimise Prime trials. Smart charging with flexibility services may result in the lowest amount of network reinforcement cost savings, if flexibility services are implemented in the same conditions as in the Optimise Prime trials. Flexibility trials in the project have shown the potential appearance of secondary peaks on the network (see Section 2.1.4.2), whose impact on the grid may become significant if flexibility services are used at large scale.

Figure 15 – Comparison between potential savings from smart charging solutions



In addition to the network-wide analysis, four specific substations were selected for further investigation to assess how a profiled connection might benefit the network at constrained points with the aim of extending the life of the asset and reduce required investment. These locations were specifically selected as their current load is nearing maximum capacity, and their Distribution Future Energy Scenarios forecast includes a high number of vans. Figure 16 shows the impact of these on peak load at a substation up to 2050 across four scenarios. The ‘no smart charging’ scenario results in the greatest load. Flexibility results in an approximately 10% reduction in peak load, versus the ‘no smart charging’ scenario. Profiled connections and smart charging result in a greater reduction of around 40% in peak load. The precise impact of the methods varies across the locations studied, but the results are similar.

Figure 16 – Contribution of vans to substation peak load, Flamstead



Diurnal profiles were also studied for the same four substations. Figure 17 shows the expected load from vans at the same substation, in 2035, at different levels of smart charging take-up. 2035 was used because this it when maximum smart charging uptake is achieved in the model (37% uptake in the high scenario and 70% in the extra high scenario). The higher uptake of smart charging results in a greater reduction in evening peak load, on the substation, but also causes a larger secondary peak in demand in the early hours of the morning. Substations modelled with more British Gas vans showed a more pronounced shift in load, reflecting the longer mileages of the British Gas fleet and more aggressive approach to smart charging, by delaying the start of charging until after 1 am.

Figure 17 – Diurnal load profile of electric vans in 2035, Flamstead

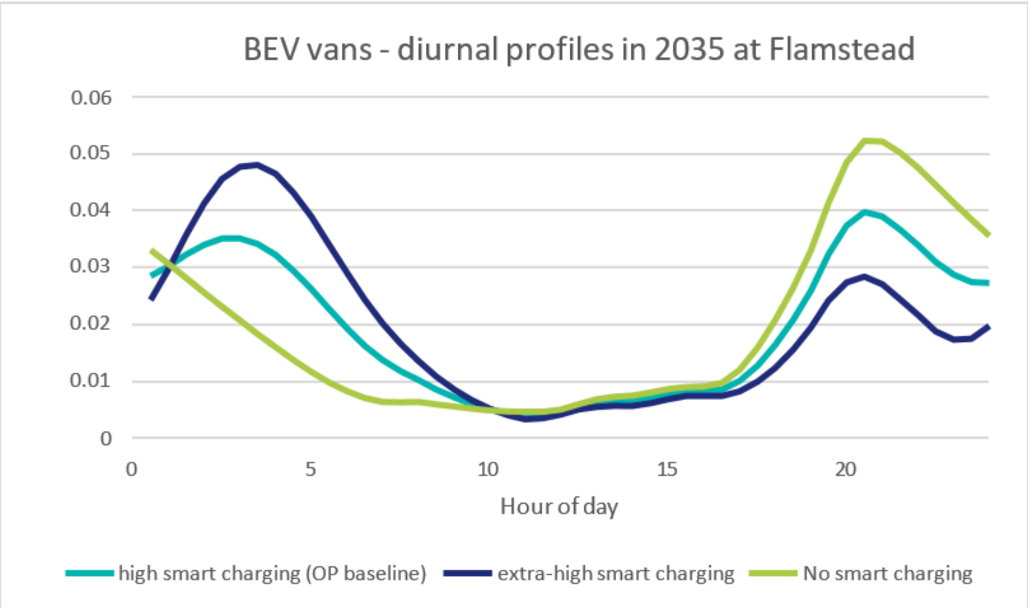
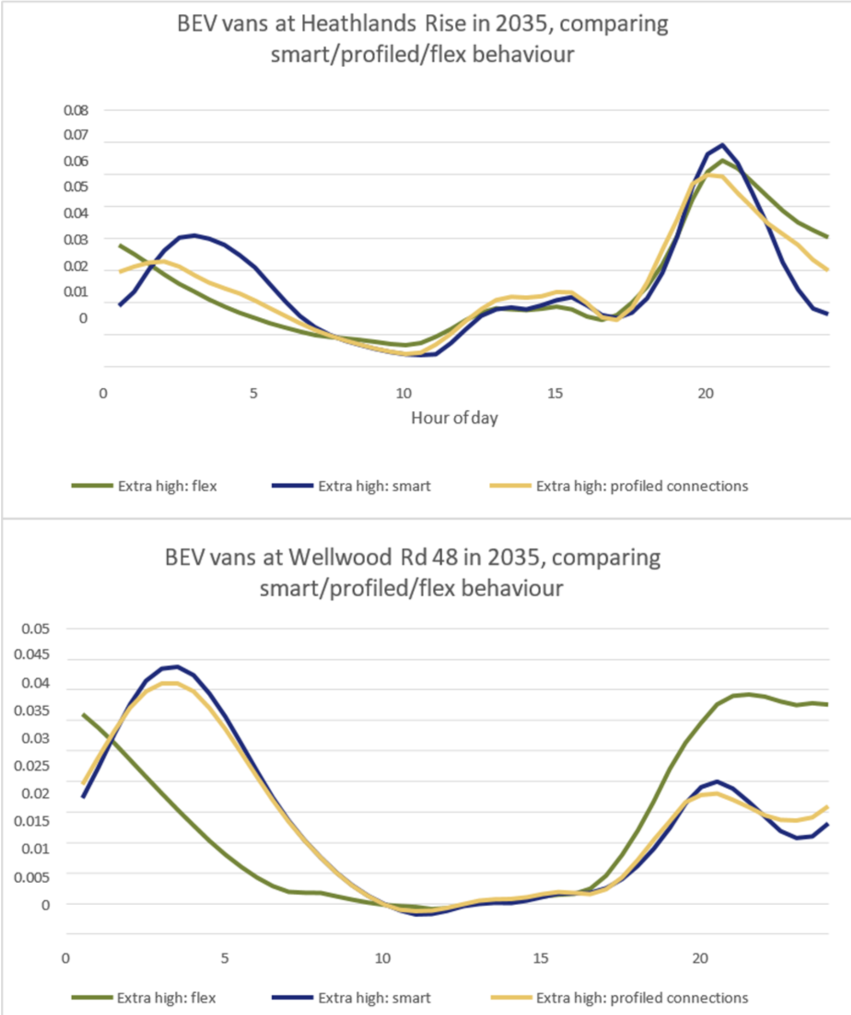


Figure 18 compares the relative impact of the use of flexibility, profiled connections and time of use smart charging at Heathlands Rise (which is dominated by vehicles modelled on Royal Mail EVs) and Wellwood Road (which is dominated by vehicles modelled on British Gas EVs) substations. Smart charging creates the highest evening peak at Heathlands Rise, however there is minimal difference between the methods. While at Wellwood Road, flexibility performs significantly worse at shifting load. This may be because the timing of the flexibility response in the trials does not correspond to these specific substations loads.

Figure 18 – Comparison of flexibility, time of use smart charging and profiled connections at two substations



The results of different degrees of smart charging uptake for PHVs was also analysed which confirmed that the difference in load, brought about by increasing smart charging, was minimal at all of the substations.

In conclusion, the analysis of network impacts has resulted in the following key insights:

Smart charging has a beneficial impact on network upgrade costs

The use of the Optimise Prime trial 'smart charging' profiles led to reductions in reinforcement costs and volumes; lower total reinforcement costs, fewer mapped distribution network asset upgrades and lower demand from fleet vans and PHVs at the time of peak demand at specific substations' peak. While new secondary peaks in EV load were created overnight by smart charging of commercial EVs, this method still reduced network reinforcement costs overall.

Flexibility and Profiled Connections reduced load at times of substation peak

At the times when individual substations experience their peak demand, the use of flexibility services and profiled connections have been modelled to reduced load. In the example in Figure 16 this was by up to 10 and 40% respectively versus a situation with no smart charging.

The difference between the impact of the different managed charging scenarios was limited

Plug-in profiles aimed to replicate the observed charging behaviour in time-of-use tariff based smart charging, flexibility services and profiled connections. Overall, **all managed charging methods resulted in an improvement over the unmanaged scenario**; however, the magnitude of **the difference between the managed charging methods was much smaller**.

Looking at the distribution networks in 2050, flexibility and profiled connections resulted in less benefit to the overall network as a whole than time of use smart charging. This was in part due to the relatively limited behavioural changes achieved in the trials, where events were limited in either duration or magnitude by limitations put in place to protect fleet operations.

In general, smart charging based on time-of-use tariffs led to the lowest reinforcement costs and volumes, lowest total reinforcement costs, fewest distribution network asset upgrades and lowest demand of fleet vans and PHVs at the time of a specific substation's peak. 'Extra high' smart charging (70% of vehicles participating in smart charging by 2030) resulted in the greatest impact, followed by 'high' smart charging (35% of vehicles participating by 2030). However, at one of the four substations studied in more detail, the flexibility scenario resulted in the lowest contribution to peak demand.

In normal operations, a flexibility request or profile would be created to address specific local constraints. Creating a generalised profile from the flexibility and smart charging trials (which were generally designed to maximise response of the assets in the trial) and applying it across the whole region may have resulted in less of an impact than if bespoke flexible profiles could have been created for local constraints. The way in which the results differ across locations highlights how having a range of different smart-charging based solutions which can be deployed by the DNO in the most appropriate circumstances is advantageous.

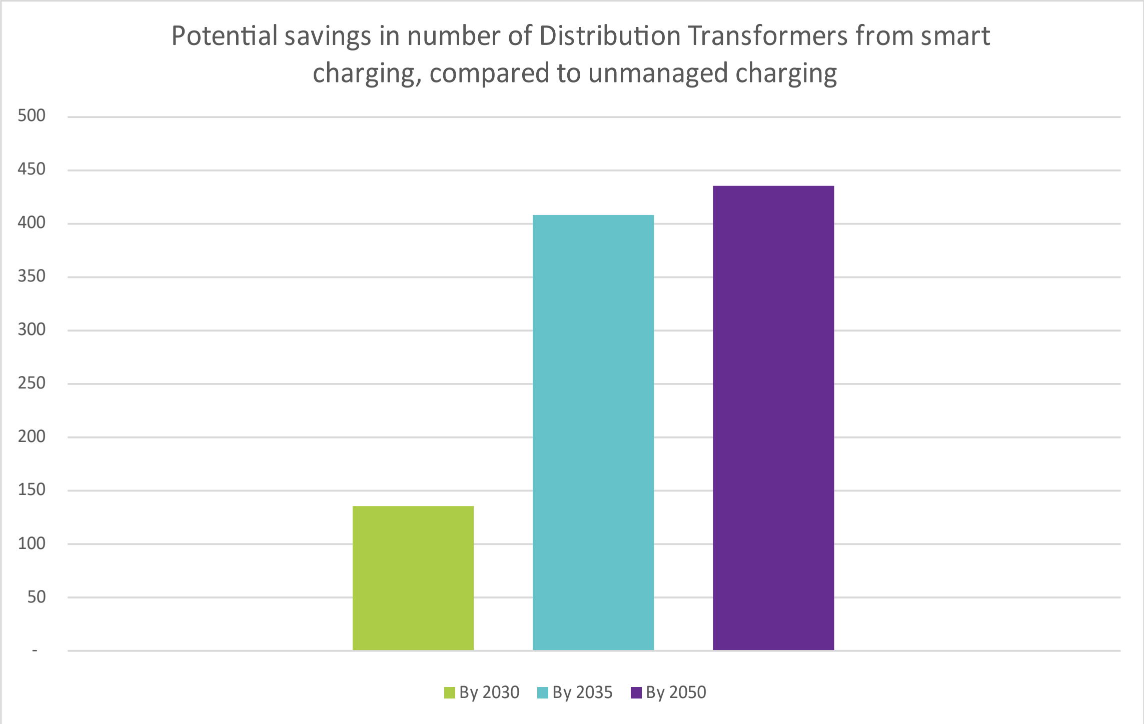
The Optimise Prime EV data helps improve network forecasting capabilities

The collection of granular EV data on driving and charging behaviours in Optimise Prime allows DNOs to model the potential impact of electric commercial fleets charging on the network. Specifically, changing EV behavioural input data from the SFS' pre-existing approximative default data to Optimise Prime data led to a larger change in reinforcement requirements than changes in smart charging uptake. The main drivers for reinforcement reduction include differences in assumed in vehicles daily mileages, vehicle efficiencies, and charging load peak times due to many vehicles in the depot and PHV segments charging in the afternoon or late at night, which does not impact upon the peak demand in the network.

Smart charging can reduce the number of transformers required to supply fleet and PHV electrification, however, seems to have very little impact on cable upgrades required

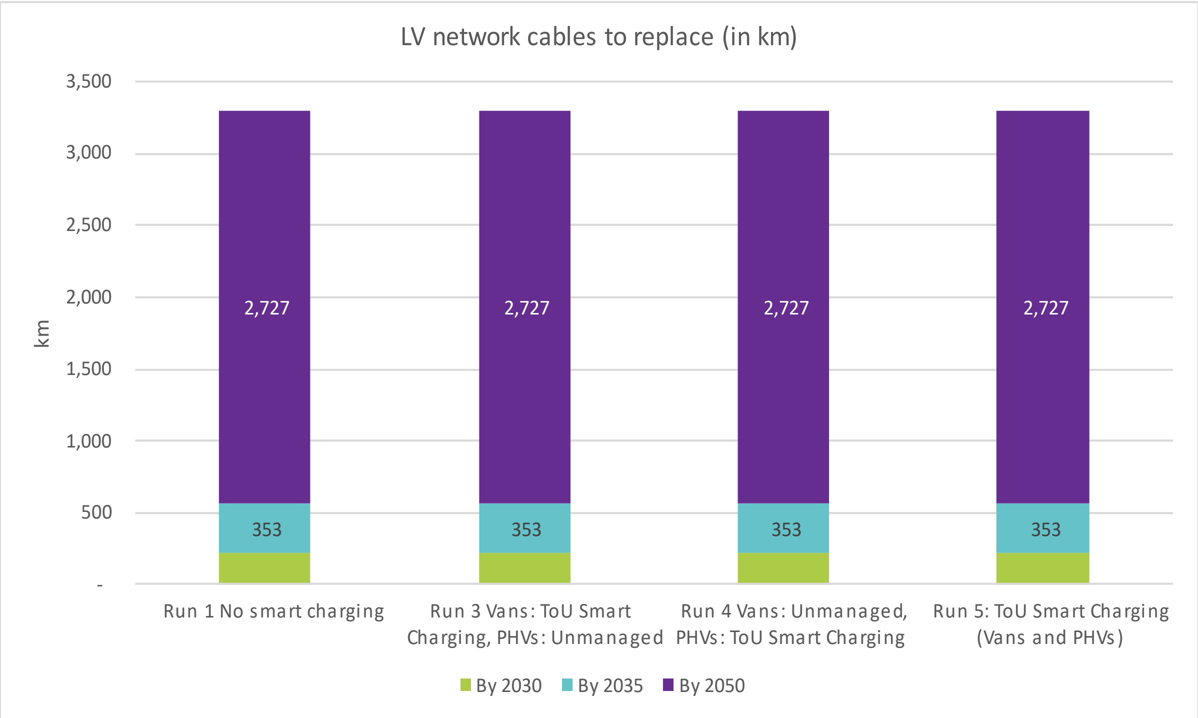
The growth of EV load modelled with the SFS shows that the demand from commercial EVs contributes to the need to upgrade transformers. Figure 19 shows how smart charging could result in a reduction of the number of transformer upgrades.

Figure 19 – Potential savings in number of distribution transformers requiring reinforcement



The model suggests that there is likely to be a more limited impact on cables. Figure 20 below shows that the volumes of cables to be replaced is similar in the unmanaged charging and smart charging scenarios. As a result, most of the benefits from smart charging come from avoiding or deferring the upgrade of transformers.

Figure 20 – Length of LV cables to replace under different scenarios



2.1.3 Mitigating energy demand from EVs – Smart charging

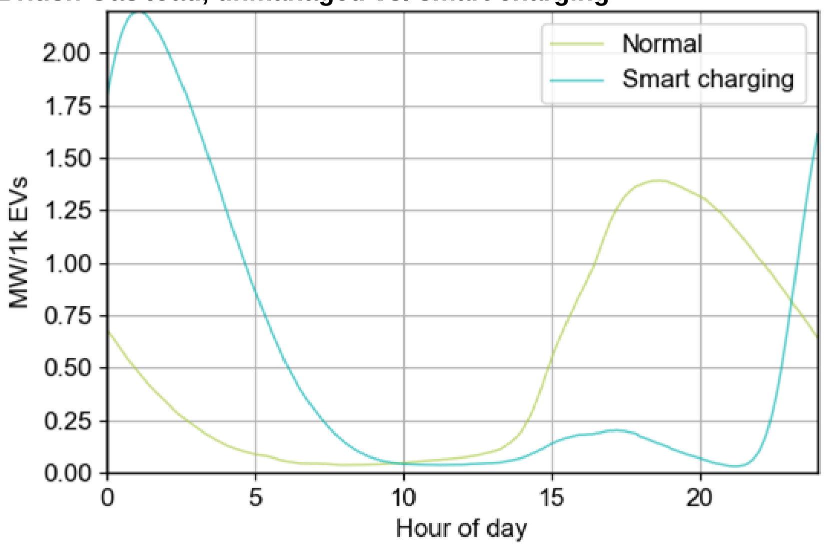
Smart charging is defined as the management of EV charging load. In order for CP users to change their behaviour, various incentives can be used. In the Optimise Prime trials, charging was driven by electricity prices in order to reduce the overall cost of charging. Smart charging represents an essential lever to mitigate demand from EVs and is necessary to support more complex interventions such as demand response and profiled connections. In addition to the use of the project methods, the project also trialled time-of-use smart charging based either on tariffs or wholesale costs.

Use of the Strategic Forecasting System showed that use of smart charging reduced upgrade costs at the network level and reduced peak load at individual substations. Time-of-use smart charging was the most effective of the methods modelled.

2.1.3.1 Home

In the British Gas trial, demand was moved to the cheapest period of the night, based on wholesale prices, provided that this allowed the EVs to fully charge before they were needed the following morning. Charging of vehicles plugged in to the British Gas CPs could be suspended until the low-price period began. Drivers had the ability to override this suspension, however use of this feature was minimal. Smart charging produced a significant shift in load vs. unmanaged charging, as shown in Figure 21.

Figure 21 – British Gas load, unmanaged vs. smart charging

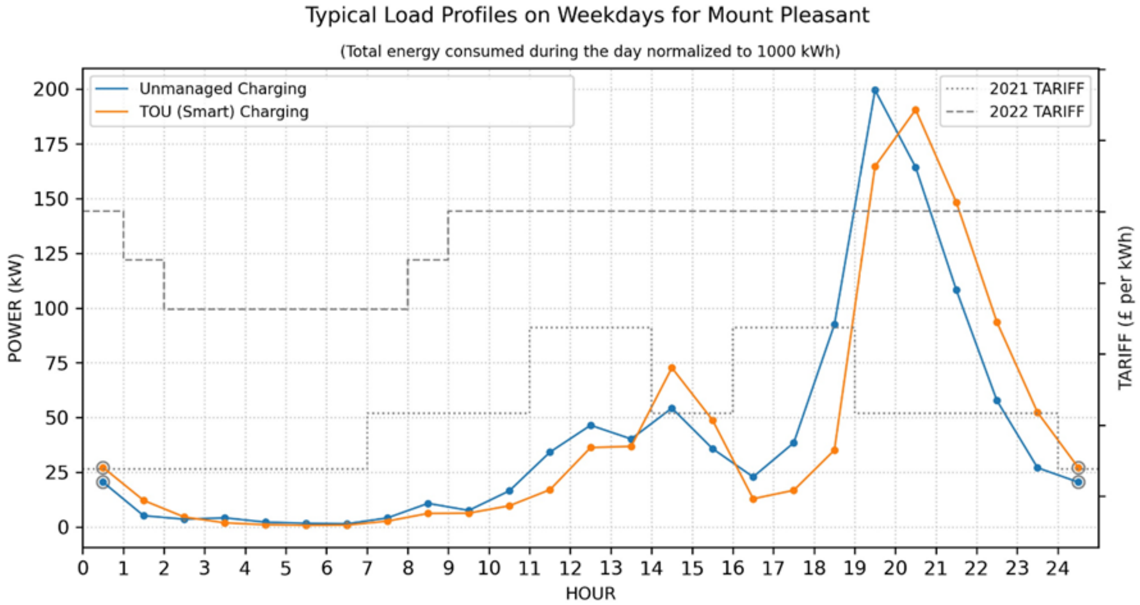


The peak load at 19:00 could be reduced by 1.05 MW for every 1,000 EVs, by smart charging, and moved to start after 21:00. However, if the load is shifted to start at a particular time, for example following prices, a new peak will be created overnight, and this peak could be 66% higher than the original peak. This occurs because the staggered charging start times are condensed into a shorter period – artificially staggering these times could reduce this impact, but would not eliminate it unless staggered over a very long period.

2.1.3.2 Depot

A different approach to smart charging was taken at the depot – reducing the amount of charging in line with an existing time-of-use tariff. The depot charging was also subject to a minimum charge rate of 6A/1.4kW, a measure taken to protect Royal Mail's operations in the event of the loss of CP control. Figure 22 compares the unmanaged and managed charging load at a Royal Mail depot on an average weekday.

Figure 22 – Unmanaged vs smart charging load at a Royal Mail depot



In this case, there was a much-reduced response to smart charging, generally delaying the peaks in demand by a short period, for the following reasons:

- The unmanaged load does not normally peak during the time of highest power prices
- The minimum charge rate does not allow the load to be fully curtailed at peak times, and when the lowest rate comes into effect after midnight, most vehicles are fully charged.

A consequence of the reduced load shifting is that the effect of a higher secondary peak is avoided. If the load could be fully constrained, and moved to start charging at a specific time in the night, it is likely that a secondary peak similar to that seen in the WS1 trial would be observed.

2.1.3.3 Mixed

It was not possible to test the smart charging of PHVs as part of the trials. Analysis of the Uber trip data found that 77% of the mixed trials fleet charged off-shift, of which a much smaller percentage charge at a private CP, at home. In the future, when CPs are pre-programmed to charge outside of the peak times of 08:00 – 11:00 and 16:00 – 22:00 on weekdays, this might reduce the peak by 1 MVA for every 1,000 EVs charged at home (an equivalent amount to the home trials). In addition, if the PHV fleets signed up with an aggregator, who managed the charging on the driver's behalf, avoiding peak times, this may also have the same impact on reducing the peak.

2.1.3.4 Insights

Smart charging can be very effective at changing load patterns, but the incentives driving the smart charging behaviour can impact greatly on how useful this behavioural change is

The two trials of smart charging, based on two different control methodologies, have shown that peak EV load can be shifted away from times of maximum network constraint. However, if all assets are following the same price signals to minimise cost, it can result in an even higher load at another time. It will depend on local constraints as to whether this creates a greater problem for the distribution network.

Reduced levels of smart charging may sometimes be more beneficial in balancing load

In the Royal Mail case, although the change was less impactful, the load was moved slightly from the peak demand period (reducing by approximately 20% on average at the time of peak load) and did not generate a significant secondary peak (13% higher). There may be situations where less dramatic changes like this (or a variety of smart load control methods) may be beneficial in balancing load throughout the day.

2.1.4 Mitigating power demand from EVs – Method 1: Flexibility services

The Optimise Prime flexibility trials were run throughout the trial year and involved the provision by the WS1 and WS2 fleets of three different flexibility products, the key details of which are summarised in Table 8.

Table 8 – Flexibility product comparison

Metric	Product A	Product B	Product C
Product type	Firm forward option	Day ahead	Intraday
Bid timeline	Month (or longer) ahead	Day ahead	Hour ahead
Basis of payment	Availability and utilisation	Utilisation only	
Settlement method	Meter data from event is compared to most recent five week or weekend days (excluding flexibility events and outliers)	The provider gives a schedule of load at the time of bid. This schedule is compared against meter data to judge the achieved turndown.	
Settlement	Pay as bid	Pay as clear	Pay as bid
Accuracy incentive	Availability payment is reduced if less than 90% of required response is provided, and not paid if average response falls below 60%	The payment is subject to a schedule accuracy factor. This factor is based on the accuracy of the provided schedule between 15:00 and 21:00 during the week of the flexibility event.	
Participants	Royal Mail fleet	Royal Mail and British Gas fleets	British Gas fleet
Comparable GB electricity market product	Secure	Dynamic	Real time balancing

Products A and B were trialled with the Royal Mail fleet, while products B and C were trialled with the British Gas fleet. The flexibility trials were interspersed with the other trials, such as profiled connections and smart charging with time of use tariffs at Royal Mail depots.

Overall, the Optimise Prime trials demonstrated the ability of EV fleets to provide flexibility services to the DNO. Key learnings from this include:

- Fleets can offer **flexibility at specific times**, dependent on when their shifts end and this varies by fleet. While in most cases this was in line with the network peak, some depots had earlier or later peak loads.
- Larger **aggregated** groups of vehicles can provide more reliable flexibility services when offering the same percentage of total load turn down. This is because there is a degree of unpredictability in the timing of charging for a specific vehicle, and this is averaged out in a larger group. However, in some circumstances the DNO may gain significant benefit

from a smaller group of vehicles close to where the network is constrained, even if the turndown results may be less reliable.

- Vehicle **charging profiles can vary over time**, both due to varying efficiency and changes in shift end times. This impacts the charging load and therefore the quantum of flexibility that can be offered.
- There is a **limit to the duration of successful flexibility response** (one to three hours) that EVs can provide – this is due to two factors:
  - The time available to charge vehicles without impacting operations is limited. This primarily impacts vehicles that travel longer distances or are charged infrequently.
  - The limited duration of the usual charging profile, due to lower mileages (although depots may be able to maintain a low load, this may not be low compared to usual demand). This is especially true of fleets that travel shorter distances.
- The process of offering flexibility needs to be **simple and automated**, from the fleet perspective, otherwise the cost of providing the service may outstrip the revenues available.
- **Baselining** demand can be particularly time intensive and, due to the factors mentioned above, may not always be accurate. A shorter baselining period is likely to be more accurate.
- Flexibility services were trialled alongside **profiled connections**. The outcomes from these trials are discussed in Section 2.1.5.4.

2.1.4.1 Conclusions on flexibility services

2.1.4.1.1 Comparing Optimise Prime trial results against the key flexibility measures

In the FSP, the project set out several measures against which flexibility services can be assessed. Table 9 sets out the key findings related to each measure.

Table 9 – Flexibility metrics

Measure	Finding
Cost	Optimise Prime was not able to simulate a full market with the limited number of flexibility providers in the trials. However, based on historic DNO flexibility prices, the benefits to fleets from different products were analysed – on a per vehicle basis revenue was estimated at around £215/year in the home case, provided the vehicle is located in an area where flexibility is regularly needed and charges at the required time. In general, there was no additional cost per kWh to a fleet providing flexibility, as they were most often shifting demand away from peak times. There will, however, be an overhead cost to fleets of providing flexibility services, and aggregators are likely to charge this as a percentage of revenue.
Magnitude	Across the home and depot trials, the amount of flexibility available was significantly lower than the total capacity of the EVs or the CPs. At Royal Mail depots and the British Gas fleet, no more than 25% of the site's total charging capacity could be delivered consistently as flexibility. The 300 vehicle British Gas flexibility groups demonstrated ability to reduce demand by between 400kW and 1MW, while the largest Royal Mail depot (87 sockets) achieved 100kW turn-down while still delivering minimum charge to vehicles. Magnitude varied greatly with time – flexibility events must align with the end of shift time to achieve high volumes of flexibility.

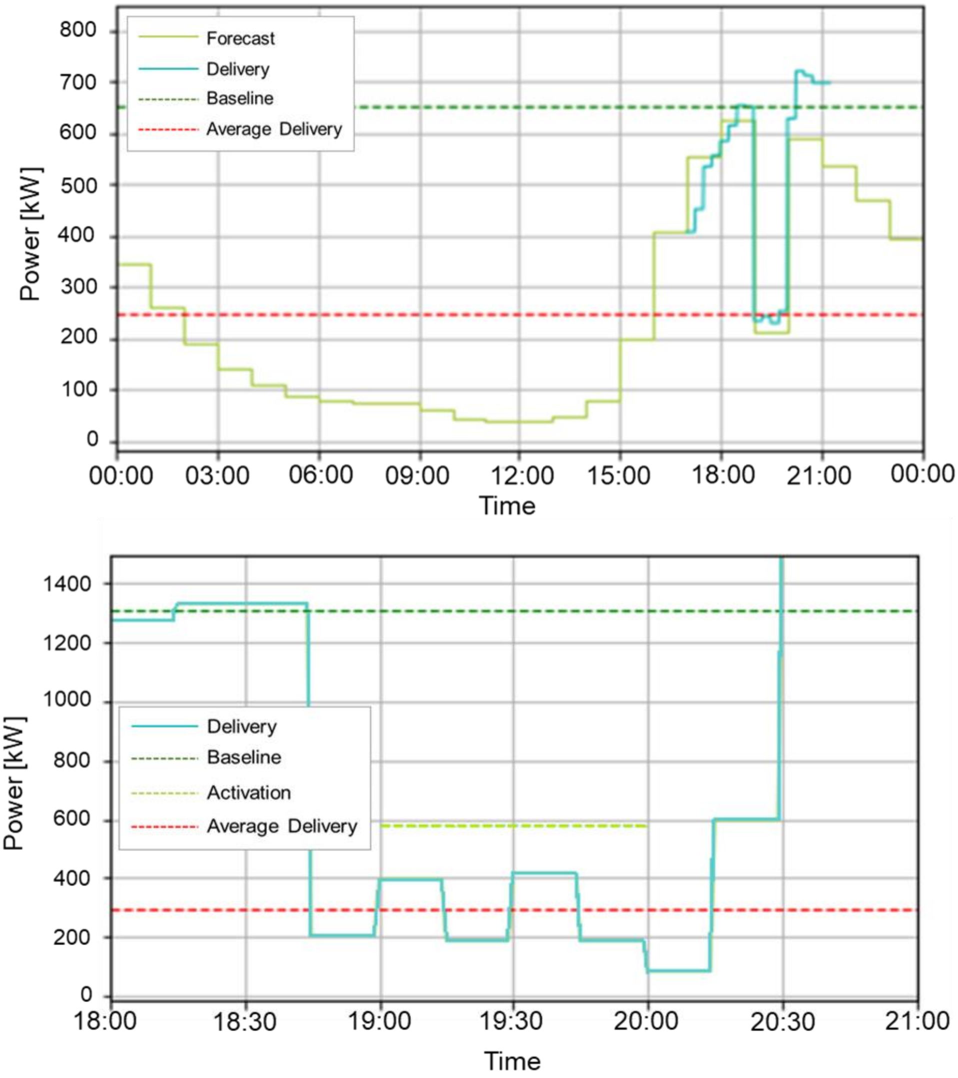
Measure	Finding
Duration	Duration is limited by the timing of the EV load at the depots, both in terms of when and for how long vehicles are parked, and how much charge they require. At Royal Mail, events of up to three hours were found to be successful, with one hour being optimum. Longer events resulted in lower amounts of capacity bid or failure to deliver. The British Gas fleet delivered one hour of flexibility with 95% accuracy, while it was modelled that up to four hours of flexibility could be offered by 22% of this fleet from 16:00. Longer and later events could rely on increasingly small proportions of the fleet.
Responsiveness	In both trials EVs were able to respond to flexibility requests within three minutes. This is generally sufficient for participation in DNO flexibility services. Depot charged EVs responded more slowly than the home-based fleet (90% of CPs responded within two minutes at depots vs 99.1% within one minute at homes), as the dual CPs and shared infrastructure required the staggering of control signals. The speed of response could potentially be improved through further optimisation of the control system if needed.
Proximity	Predictability of load (and therefore flexibility) improved closer to the event. In the depot trial, the day ahead product (B) had 15% greater delivery reliability than the month-ahead product (A). The intraday product, (C), could be predicted more reliably still, but by a smaller margin. As a result, the magnitude of flexibility that could be offered reliably also increased closer to the event. Bids that required capacity to be set long in advance required respondents to be more conservative to ensure reliable delivery.
Make-up	A comparison with past flexibility competitions has shown that, from a fleet perspective, the utilisation payment only product is likely to generate more revenue, providing the flexibility is called upon on a regular basis, and is delivered with >55% accuracy. If flexibility is called less often, the product with availability will be more profitable, provided it can be responded to successfully. However, in practice, market participants are likely to set their bid prices based on calculation of the potential risk and reward in each product in order to cover costs and maximise profit.
Predictability	Predictability was found to vary between fleets based on several other factors, such as varying operations, the size of the aggregated group, the timing of load peak relative to the flexibility event and how far in advance bids had to be made. The home scenario, with a 1:1 ratio of EVs to CPs, a standard return home time and longer charging period could be predicted with 95% accuracy. Depot flexibility was more difficult to predict. Changes in operations led to changes in the timing of the charging peak. Greater numbers of EVs per CP meant that EVs charged at less regular intervals.

The following sections highlight key conclusions relating to each individual trial, and full details of the outcome of the flexibility trials can be found in Appendix 1.

2.1.4.1.2 Home

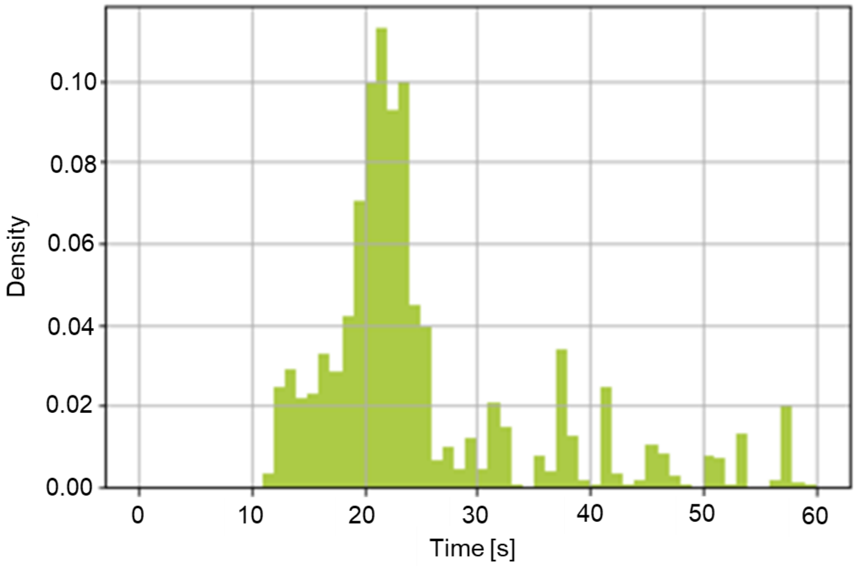
Because of the British Gas shift pattern, and in order to reduce impact on the fleet operations, the trials focused on delivering turndown between 17:00 and 19:00 for one hour, with the CPs turned off. The EVs were grouped into two flexible units (FUs), one for each of Products B and C. An example of the response to each type of event is shown in Figure 23. Baseline indicates the expected load if flexibility was not being provided in the period, forecast/activation shows the target load to fulfil the flexibility product bid for and delivery shows the actual load.

Figure 23 – Example of a response to a Product B flexibility event, above, and Product C event, below



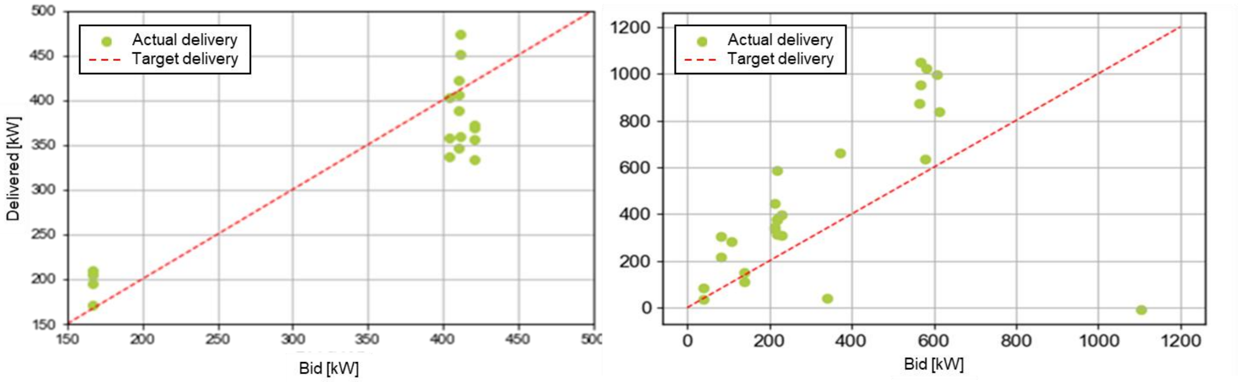
The consistency of charging vehicles of this type lends itself well to flexibility services. On average, 95% of British Gas vans would successfully respond to each turn down request and 400 kW of offered flexibility was delivered for every 300 EVs. While drivers had the ability to opt out of specific flexibility events, only a few did and the use of this feature declined over time once the drivers were comfortable that they would not be left with an empty battery. The British Gas vans were able to respond quickly to a turn down signal, with all vehicles responding within one minute, and having an average response of 25.1 seconds, as shown in Figure 24.

Figure 24 – Response time of home trial CPs



Products B and C were both successful in delivering close to the bid amount of flexibility, as shown in Figure 25. The shorter time between bid and delivery (hour ahead vs day ahead) in Product C allowed for bids to be less conservative, and generally resulted in delivery exceeding the bid amount.

Figure 25 – Results of Product B trials (left) and Product C (right)



It is important to note that for the purposes of the Optimise Prime trials, geographical location was not considered: all British Gas EVs were assumed to be in the catchment area for all events. In practice the fleet is dispersed over a wide area, so could have a much smaller group of vehicles that would be eligible to respond to a given DNO request for flexibility.

In addition, the proportion of the British Gas fleet being charged entirely at home is predicted to drop from 80% today to around 40%, by 2030, as the EV rollout includes more drivers without off street parking or the ability to install CPs. As a result, the aggregated turndown per EV is expected to decline over time. In short, home EV demand flexibility will alter over time and network planning around flexibility products will need to account for this.

2.1.4.1.3 Depot

For Royal Mail, each depot was treated as a single FU. The provision of flexibility at a variety of different times of the day and for different durations was tested, with later trials focusing on the times when each depot was most successful. Depots were split between two flexibility products: A and B.

Depots were generally able to offer and deliver reliable turndown for a single period of up to three hours in the period immediately after a shift, when peak charging load generally occurs. Beyond this it became increasingly difficult to predict available load accurately, resulting in the depots offering small volumes of flexibility, or failing to deliver accurate turndown.

The average amount of turndown achievable was up to 75% of offered turndown as a percentage of its average unmanaged EV load (kW) across all sites. This was due to several factors, including not all EVs plugging in at the same time, not plugging in every day, some EVs not being able to charge at the full rate of the CP because of battery limitations, EVs only needing to charge for a short duration and a minimum charge rate being implemented meaning the EVs were always charging, even during a flexibility event.

2.1.4.1.4 Mixed

Uber does not control the charging behaviour of drivers, so the project team held discussions with commercial aggregators about whether this type of a fleet might be able to offer flexibility services.

The opportunity cost of charging is significant, at around £25 per hour, which suggests that provision of flexibility services when on-shift is highly unlikely. There is greater potential for flexibility with off-shift charging: one future business model might be for Uber to team up with an energy supplier/aggregator to offer a tariff which would allow Uber drivers to earn (or save) money by allowing the aggregator to control their home CP and offer turn down services on their behalf (in the same way as Centrica) when off-shift.

This could unlock 1 MW in controllable load, for every 1,000 Uber EVs charged at home, using the British Gas fleet as a proxy for home flexibility performance. It is important to note that the peak time for Uber off-shift charging is 20:00, i.e. outside of peak hours, so the benefits of this flexible load may be more limited. Research from Transport for London[1] has found that 57% of Greater London residents' vehicles are parked off-street, though this varies significantly by borough. Analysis from surveys of Uber drivers found that although just over half of drivers charge at or near home, over 80% of charging takes place at public charge points.

2.1.4.2 Insights

There are many factors which affect the delivery performance during a flexibility event, with the ability to forecast accurately relying on the efficiency and consistency of depot operations. Key factors identified as impacting the success of flexibility events included:

The short and sharp load peaks at some depots limit the duration and volume of flexibility that can be offered

In an unmanaged scenario the Royal Mail load curve peak is short and sharp so the peak turndown is available for a limited time window (less than three hours). This differs from many other load types that take part in demand response.

- The timing of this peak can vary over time as schedules react to changing workloads across seasons, making long-term prediction difficult
- The vehicles can only provide flexibility when they would normally be charging. This reduces the ability of depots to participate in products that require a long period of

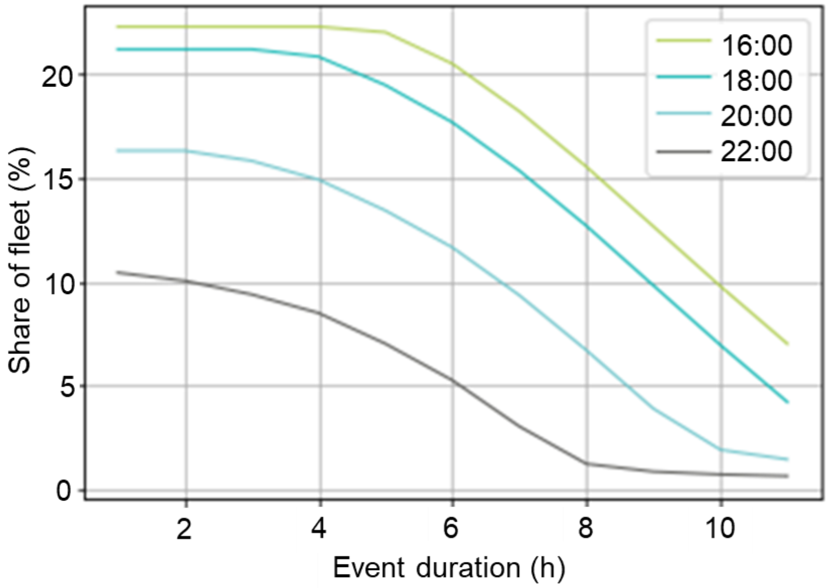
[1] Table 4.22 of 'Travel in London Report 12 data', found at https://tfl.gov.uk/corporate/publications-and-reports/travel-in-london-reports

availability. The flexibility window required by the DNO may not align with this period depending on the specific depot and local constraints

- The flexibility window required by the DNO may occur when the vehicles are normally plugging in or finishing charging. This period of load change is especially difficult to predict, reducing the amount of flexibility that can be offered by the participant
- Where two flexibility events were tested in the same day, or events were longer than three hours, the amount of flexibility that could be offered consistently over the period was low, due to the short charging durations

The British Gas fleet generally travelled further each day than the Royal Mail EVs and plugged in at a relatively consistent time each evening. Analysis has shown that over 20% of the fleet can provide flexibility for up to four hours if the event starts at 16:00. The longer and later the event falls, the fewer vehicles will be able to respond because the EVs need time to be charged for the next day's work, as shown in Figure 26.

Figure 26 – Share of British Gas fleet able to provide flexibility by request time and duration



There is significant variation between weekdays and weekend loads and between individual days of the week

While there are general trends, the size and timing of peaks can vary significantly between and across weekdays and weekend days. For example, at Royal Mail depots, load on Sundays was significantly lower than load on Saturdays. Amongst British Gas drivers, load on Fridays was lower than Monday-Thursday, as drivers had two days to charge before their Monday shift, as shown in Figure 2.

This variation limits the amount that can be offered in products that require the same capacity to be bid on each day, or every working/non-working day.

Businesses will be conscious of how flexibility provision may create operational risk, and may limit flexibility participation as mitigation

A number of limitations put in place to reduce risks to project partners reduced the amount of flexibility that could be offered and delivered in the trials:

- As a result of the minimum charge rate at Royal Mail depots, where flexibility events started several hours after a shift finished, the turndown that could be offered and delivered was significantly lower because many of the EVs would have reached a high state-of-charge (SoC), or finished charging, reducing the ability to offer load turndown

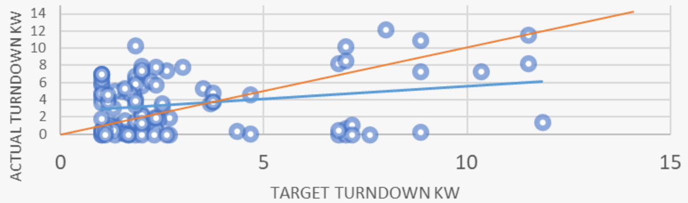
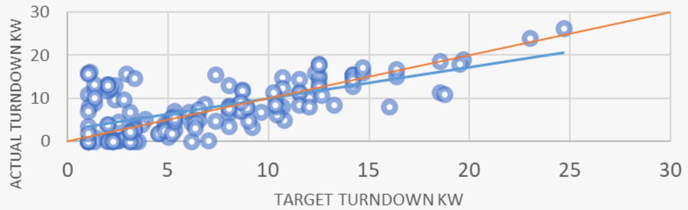
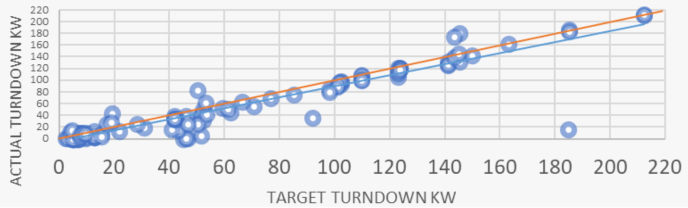
- The amount of flexibility that could be offered from each vehicle was also reduced by 1.4kW compared to a fleet that could turn off completely
- For the final flexibility trial, the Royal Mail CPs at one depot were turned off fully and the amount of flexibility turndown increased, roughly doubling the response.

In a business-as-usual scenario, other risk mitigations could be considered which have less impact on ability to shift load. For example, by limiting the duration of flexibility events (as was the case in the WS1 trial), implementing a manual failsafe to reset charging speeds or as a result of the fleet becoming confident of the system's reliability.

The size of the depot impacts upon the reliability of demand response provision

The size of the depot was a significant factor affecting how much flexibility could be offered and how reliably it could be provided. The large depot (>100 EVs) was more reliable than the small depots (25 EVs) because small variations in day-to-day routines had a proportionally smaller effect on the total load. Figure 27 shows how the larger depot was able to align delivery more closely to the target turndown amount, while also turning down a greater proportion of its load.

Figure 27 – Flexibility results by depot size

Depot	Actual vs target turndown	Turndown as a % of unmanaged load
Small		**42%** on average
Medium		**50%** on average
Large		**63%** on average

CP to vehicle ratio has an impact on the predictability of flexible load

The ratio of vehicles to CPs varied between locations – homes and some depots had a 1:1 relationship, allowing vehicles to be charged every day. Other depots had up to three vehicles per CP, resulting in each vehicle charging less frequently. While this resulted in higher charger utilisation, it also made it more complex to predict when and for how long a particular vehicle would charge.

Operational procedures at specific depots impacted the timing and predictability of load

There was no standard procedure for charging vehicles at Royal Mail sites – the variability in load can be seen in Figure 6. While most sites plugged in vehicles when they returned from shifts, one site often charged its vans early in the morning before shifts began. Ad hoc charging also took place during the day at unpredictable times. Other factors, such as physical access to parking spaces impacted the number of vehicles able to charge at any time.

- **Specific to the trial,** Hitachi controlled the charging of Royal Mail's EVs via a system which relied on identification of vehicles via radio-frequency identification (RFID) cards. To maintain Royal Mail's operations, only recognised vehicles were involved in the optimisation and flexibility provision. At times unknown RFID cards were introduced, resulting in CP load that could not be controlled and EV load increasing during the flexibility event. This was resolved as the trials progressed through the recognition and registering of unknown RFID cards.

A trade-off needs to be made between the value of more reliable flexibility, versus a greater volume of flexibility

GB DNOs are committed to using demand side response to reduce the need for network reinforcement as part of their flexibility first approach. As a result, it is necessary to encourage the provision of more flexibility services from a wider range of sources, such as electric vehicles.

The Optimise Prime trials have shown that there is a clear difference in the reliability of flexibility services provided by different EV fleets, due to the variability of the load. If flexibility providers are not paid for flexibility provided due to poor performance they will likely take a conservative approach to making bids for services, based on a worst-case scenario. This would limit the volume offered and supplied to the DNO.

Conversely, if the DNO were value under-delivery, there would be less certainty of the extent to which flexibility could be relied upon, so a greater quantity would need to be procured.

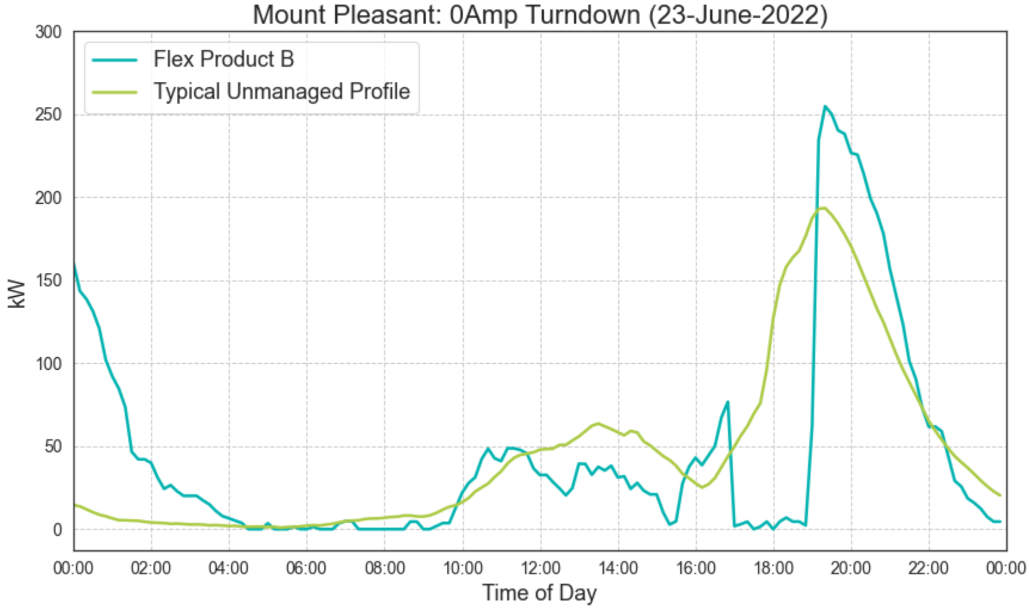
To encourage providers from a wider range of sources, different flexibility products with different reliability requirements need to be offered. The price of flexibility can be altered relative to the reliability to offset the requirement to buy more capacity and ensure value for the DNO.

A 'secondary peak' can appear at the end of a flexibility event and should be mitigated. This peak is driven by the magnitude of the demand response.

The Optimise Prime trials have shown that shifting demand through provision of flexibility services can produce a new peak once the flexibility event has ended, similar to the secondary peak from smart charging discussed in Section 2.1.3, and shown in Figure 28. The size of this peak is driven by the amount of flexibility that has been delivered.

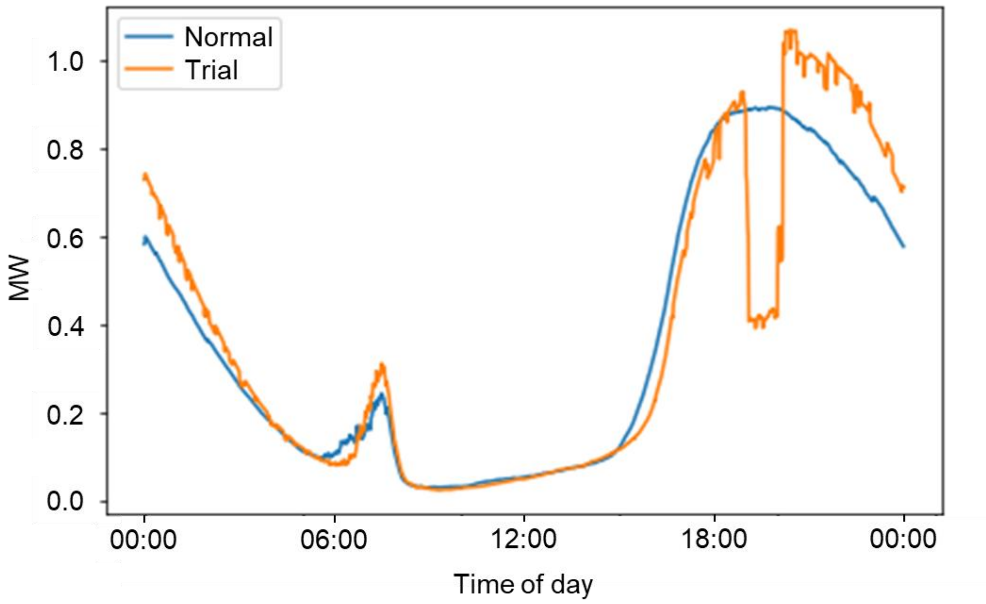
In Royal Mail trials, where a minimum charging level of 6A was implemented, the new peak was often lower than the peak that was being avoided, as some vehicles will have completed charging during the flexibility event. When 100% of load was turned down the resultant secondary peak was 32% higher than the usual daily peak, as it resulted in all vehicles charging simultaneously.

Figure 28 – Full turn down of Mount Pleasant Depot and resulting secondary peak



Across the British Gas fleet, where around 50% of the fleet was turned down at any one time, the resultant secondary peak was 12% higher than the unmanaged peak, as shown in Figure 29.

Figure 29 – Flexibility trial vs normal charging behaviour in British Gas fleet



The settlement process needs to reflect the type and reliability of flexibility being provided

Settlement and baselining methodologies can have a significant impact on how delivered flexibility is measured and how providers are rewarded. The settlement process, which estimates how much flexibility has been delivered, must be carefully considered.

For example, when load is ramping up or down naturally, baselining against the previous half-hour period will often give a misleading result. The load shapes from the EV fleets show that this is generally the case with unmanaged charging – there is relatively little time when the load is stable. Five different baseline techniques have been compared based on trial data in order to identify the considerations when deciding on settlement methodology, as shown in Table 10.

Table 10 – Baseline methodologies compared using trial data

Baseline	Methodology
Optimise Prime Baseline Used by Hitachi to make bids	- Two to four weeks of data - Only includes days when a site is not providing flexibility services or any other charging suppression methods - Each day of the week treated separately - 30-minute mean kW per charger and per depot
60-day Baseline Using as much data as possible	- 60 days of data - Days when the site is not providing flexibility service - Days of the week combined to weekdays and weekends - 30-minute mean kW per charger and per depot
Two weeks baseline (average of two of the same day)	- Average of the last two weeks of data where the site is not providing flexibility services or any other charging suppression methods - Each day of the week treated separately - 30-minute mean kW per charger and per depot
UK Power Networks Baseline Used to calculate settlements	- Five qualifying days (five most recent weekdays or weekends) - Days when the site is not providing flexibility service - Days of the week combined to weekdays and weekends - 30-minute mean kW per charger and per depot
Adjusted Baseline Based on P376[2] BL01	- Up to 10 weekdays and four non-working days - Days when the site is not providing flexibility service - Days of the week combined to weekdays and weekends - 30-minute mean kW per charger and per depot (over all available data for weekdays and over middle two days for non-working days) - Adjusting the baseline with metered data over the three-hour period up until one hour ahead of the relevant Settlement Period when the service starts to deliver

Table 11 shows the outcome of the comparison of the different methods, showing the average difference, in %, between the forecast and actual load for four depots at a specific time. Positive figures represent an over-estimation and negative figures an under estimation.

[2] P376 is a modification to the Balancing and Settlement Code which sets out methodologies for calculating baselines for use in settlement of services supplied in the Balancing Market

Table 11 – Outcome of analysis of settlement methodologies

Depot	Day	Average load 18:00-20:00 [kW]	Optimise Prime baseline, average diff [%]	60-day baseline, average diff [%]	2 weeks baseline, average diff [%]	UK Power Networks baseline, average diff [%]	Adjusted baseline, average diff [%]
1	Weekday	24.7	-8%	-8%	-45%	-12%	11%
2	Weekday	167.9	-6%	-7%	-46%	-39%	-17%
3	Weekday	18.4	40%	38%	-16%	-6%	109%
4	Weekday	53.0	-6%	-6%	-57%	-34%	3%
1	Weekend	8.4	-17%	-10%	2%	-34%	-32%
2	Weekend	8.5	-16%	3%	-12%	-31%	-82%
3	Weekend	12.9	-15%	-21%	20%	-26%	10%
4	Weekend	31.1	-73%	-73%	-6%	-56%	-109%
Mean absolute differential			**23%**	**21%**	**20%**	**30%**	**47%**

While the analysis showed that there was a degree of error in all baselining methodologies, the following observations are made based on the results:

- Data used for evaluation should be as close to the event as possible, to avoid any effects of seasonal variation
- Evaluation period should have the same characteristics that are expected during the event (no/same charging suppression methods)
- Each day of the week should be treated separately
- Two or more occurrences of each day of the week are recommended (two or more Mondays, two or more Tuesdays, etc.)
- In-day adjustments, where the baseline is increased or decreased based on load earlier in the day, may not be suitable for situations where there are variations in plug-in time (which occurred in the Royal Mail trials), rather than the magnitude of load, because the load when vehicles are charging is not relative to load earlier in the day.

2.1.4.2.1 Product comparison

The three flexibility products trialled in Optimise Prime include a range of features.

Table 12 describes the three flexibility products trialled in Optimise Prime with differing bid, dispatch and settlement processes. Table 12 highlights some of the key features of each, and how this impacted on the provision of flexibility services.

Table 12 – Comparison of the three flexibility products

	Product A – Firm Forward	Product B – Day ahead	Product C – Intraday
Forecasting	Accurate forecasting of load a month in advance is difficult to achieve, resulting in a trade-off between providers being conservative in their bids in order to assure they can be delivered, or accepting that contracts may not always be completely fulfilled.	Accurate forecasting of load a day ahead can still be challenging, but it is generally much more accurate than forecasting a longer period ahead.	Forecasting is easier for this product, as closer to delivery it can take into account the current status of EVs or changes on the day. Centrica was able to be less conservative when making bids in product C, although the volume of flex available and delivery success was similar to Product B.

	Product A – Firm Forward	Product B – Day ahead	Product C – Intraday
Bid structure	A single turn-down amount was requested for the whole (two to three hours) flexibility window. Given the peaking shape of the load from EVs, this limited the amount of flexibility that could be offered to the lowest point during the flexibility window. In early trials, a single amount was requested for all days (or all working days). This resulted in very low bids, based on the day of the week where least load was available.	A schedule is submitted day-ahead for load at each half hour of the day, together with an offer to turn down against requested periods. This granularity of bid allows the amount offered to be maximised, as load variation over each half hour is relatively minimal.	Bids follow a similar form to Product B, except bids can be made separately for each half-hour of the day, up to one hour before delivery.
Settlement & Payment	Settlement based upon a calculated baseline. The accuracy of a baseline in predicting EV load can vary significantly. Variability of performance may balance out variability in baseline, but the supplier is not paid for over-performance but is penalised for under-performance and so does not benefit. Product A offered availability and utilisation payments. Due to availability payments this product is comparatively more attractive to participants the less the flexibility is called upon. However, availability payment is reduced as reliability reduces, with a very sharp reduction to zero payment if reliability drops below 60%, impacting less predictable fleets.	Settlement is against the submitted schedule. This is simpler as the provider can target a specific load. However, this does open the schedule to the risk of manipulation, by over or under stating load – a schedule reliability factor mitigates this risk. As only utilisation payments are made, fleets benefit most from this product if they are called upon for flexibility regularly. Based on comparison of past DNO flexibility competitions, a utilisation only product will provide more revenue for a fleet if at least 10% of offered bids are successful and schedule accuracy exceeds 55%.	Settlement and payments in Product C follow the same process as Product B, with the same process for schedule accuracy.

	Product A – Firm Forward	Product B – Day ahead	Product C – Intraday
Value to DNO	A product agreed in advance such as Product A provides some security to the DNO that they can rely on flexibility in the future. If agreed a year or more ahead it may be used to offset investment in network upgrades. Lower reliability may require the DNO to purchase and dispatch more capacity than is required. The product can be dispatched in near-real time, and so can be used to counter unexpected faults.	Allows for DNOs to procure for any additional capacity requirements that could not be arranged ahead of time. With dispatch taking place day-ahead, it can be used to manage scheduled disruptions, but not unexpected faults. While there is value from the higher accuracy in forecasts from day-ahead, this is offset by uncertainty over whether sufficient capacity will be bid.	Intraday markets are not widely used by DNOs. The trial has shown that an intraday product can technically be provided, should a DNO have a requirement for such a product. However, the benefit from offering such a product is limited and may not offset the technological and process complexity of continuous bid and dispatch.

2.1.4.2.2 Opportunity cost – the ability of fleets to participate in other flexibility markets

DNO flexibility services are not the only option available to fleets which are able to offer demand response. Optimise Prime worked with Cornwall Insight to investigate the range of flexibility services that may be open to participation by fleets such as Royal Mail and British Gas, given their performance in the trials. DNO services would potentially have to compete with these products for available flexible capacity.

Flexibility opportunities range in their requirements and commercial value, making the provision of certain services far more suitable for those EV fleets trialled in Optimise Prime. A comparative analysis of the requirements, commercial value, and suitability of services for Optimise Prime fleets is shown below in Table 13.

Table 13 – Suitability of flexibility services to fleet operators

Revenue stream	Technical, commercial and contractual accessibility	Commercial value	Key Optimise Prime considerations
Balancing Mechanism (BM)	Proven route to market via aggregated unit but technical and entry hurdles, with EVs negligible to date	High values can be achieved but likelihood of being called on is uncertain and constrained by availability	Positive opportunities for aggregated participation, with regulatory workstreams in Virtual Lead Party and Wider Access could improve accessibility
Firm Frequency Response (FFR)	Availability windows a problem Response speed doesn't meet requirements	Fleet availability aligned with most traditionally most valuable EFA block Uncertainty over long-term role of the service	Prohibitive entry and delivery requirements limit near term opportunities for Optimise Prime Fleets
Dynamic Containment (DC)	Required response speeds prevent participation for both fleets	Highest revenues amongst the DC, DM, and DR services, with positive correlation to fleet availability windows. However, values expected to erode over time via increased competition	Prohibitive entry and delivery requirements limit near term opportunities for Optimise Prime Fleets

Revenue stream	Technical, commercial and contractual accessibility	Commercial value	Key Optimise Prime considerations
Dynamic Regulation (DR)	Required response speeds prevent participation for both fleets	Slowest response time of the DC, DM, and DR services, with competitive values seen in service to date	Prohibitive entry and delivery requirements limit near term opportunities for Optimise Prime Fleets
Dynamic Moderation (DM)	Required response speeds prevent participation for both fleets	Revenues lowest amongst the DC, DM, and DR services	Prohibitive entry and delivery requirements limit near term opportunities for Optimise Prime Fleets
Short-Term Operating Reserve (STOR)	Limited availability across windows and current fleet capacity levels may constrain access	A widely accessed service, STOR can see high levels of competition, potentially supressing value received	While a relatively accessible market, it is planned to be replaced by future reserve services
Quick & Slow Reserve (QSR)	Fleets can meet the size thresholds, depending on availability levels. Response speeds for Quick Reserve could present challenges	No completed auctions to date limits price visibility. However, the more granular delivery windows could align well with fleet availability schedules	Overall, these services could be readily accessible for the Optimise Prime fleets and should be tracked ahead of launch.
Capacity Market (CM)	Metering and performance testing present hurdles and no EV-specific definition would require DSR (demand side response) classification	Wide ranging values observed, with revenues secure and stable. Must consider de-rating factors and non-delivery risk	Work is ongoing to increase the number of technology classifications within the CM auctions, potentially providing specific EV consideration
Distribution System Operator (DSO) Services	Comparatively low technical barriers. However, highly locational nature of services could limit access	Highly variable values recorded, with additional considerations regarding utilisation. However, some lucrative values seen to date	Proven route for EV fleets to participate in flexibility services, with work to improve access and standardisation of services ongoing

The commercial strategy adopted for any commercial electric fleet should also consider the ability to 'stack' (i.e., combine with another product/service) and switch between revenue opportunities – not just the individual value of opportunities. Table 14 shows the relationships between services, indicating which are stackable. As highlighted, only Capacity Market participation is highly stackable with other services, whilst DNO services may be stackable amongst one another. Nevertheless, the short-term contracting nature of many of these services mean assets can switch between revenue streams frequently to identify the highest value opportunities.

Balancing Mechanisms offer a growing opportunity for EV fleets following the success of wider innovation trials in 2022, where Octopus Energy and National Grid ESO tested the use of 20 vehicles with V2G chargers to provide balancing[3]. The Capacity Market offers a highly stackable, lower revenue opportunity for fleets.

Frequency response services (DC, DR, DM and FFR) are unlikely near-term opportunities for Optimise Prime fleets, which do not currently have fast enough response capabilities to meet requirements.

[3] https://octopus.energy/press/octopus-energy-and-national-grid-eso-demonstrate-future-role-for-electric-vehicles-in-first-for-great-britain/

The emerging Quick and Slow Reserve markets, particularly the Slow Reserve market due to EVs being able to meet the response time requirements (<15mins), present an opportunity for Optimise Prime fleets. These should be prioritised over Fast Reserve and STOR which are being replaced by the Quick and Slow Reserve markets respectively.

With comparatively lower technical requirements, DNO (or DSO) services offer commercially attractive opportunities, particularly with ongoing work to increase participation for EV fleets. The Optimise Prime fleets are suited to DNO services, as they generally meet requirements on capacity and responsiveness. However, the highly locational nature of services may limit this opportunity, particularly for more dispersed return to home fleets, as fleets will be subject to specific requirements at given charging locations. DNO services are high variable in their requirements, some of which may not always be possible to meet considering fleet profiles. Dynamic and Secure are the more challenging – but still attainable – DNO services owing to the quick response times and long durations that may be required. Participation in other flexibility services whilst providing DNO services is often prohibited, except for the Capacity Market. This is also the case for Electricity System Operator (ESO) services.

Ultimately, by moving between and stacking revenue streams, EVs can provide flexibility services to both DNOs and ESOs to maximise their revenue potential, provided that they have the capabilities to do. The level of control and understanding of the products required to devise and implement a successful strategy is likely to lead to most fleets participating via an aggregator, rather than directly.

Table 14 – Ability to stack flexibility services[4]

Service	Wholesale	CM	BM	TERRE	NIV chasing	FFR	DC	DR	DM	Fast Reserve	STOR	DNO Sustain	DNO Secure	DNO Dynamic	DNO Restore
Wholesale		YES	YES	YES	NO	NO	NO	NO	NO	NO	NO	YES	NO*	NO	NO
CM	YES		YES	YES**	YES	YES	YES	YES	YES	YES	YES	YES**	YES**	YES**	YES**
BM	YES	YES		YES	NO	NO	YES****	NO	NO	NO	NO	NO	NO	NO	NO
TERRE	YES	YES**	YES		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
NIV Chasing	NO	YES	NO	NO		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
FFR	NO	YES	NO	NO	NO		NO	NO	NO	NO	NO	NO	NO	NO	NO
DC	NO	YES	YES****	NO	NO	NO		YES	YES	NO	NO	NO	NO	NO	NO
DR	NO	YES	NO	NO	NO	NO	YES		YES	NO	NO	NO	NO	NO	NO
DM	NO	YES	NO	NO	NO	NO	YES	YES		NO	NO	NO	NO	NO	NO
Fast Reserve	NO	YES	NO	NO	NO	NO	NO	NO	NO		NO	NO	NO	NO	NO
STOR	NO	YES	NO	NO	NO	NO	NO	NO	NO	NO		NO	NO	NO	NO
DNO Sustain	YES	YES**	NO	NO	NO	NO	NO	NO	NO	NO	NO		NO	NO	NO
DNO Secure	NO*	YES**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO		YES***	YES***
DNO Dynamic	NO	YES**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES***		YES***
DNO Restore	NO	YES**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	YES***	YES***	

* Varies by DNO. Some dispatch for Secure in advance (e.g. week-ahead for WPD) so the relevant Balance Responsible Party (BRP) can trade to that position. Others dispatch closer to real time.
** No obligation not to provide but could expose the provider to risk of Capacity Market (CM) penalty.
*** Cannot dispatch for both Restore and Dynamic or Secure services in the same time period, but DNO has visibility of all services for which a FlexibilityService Provider (FSP) is available so can optimise dispatch.
**** Currently only stackable with BM bids.

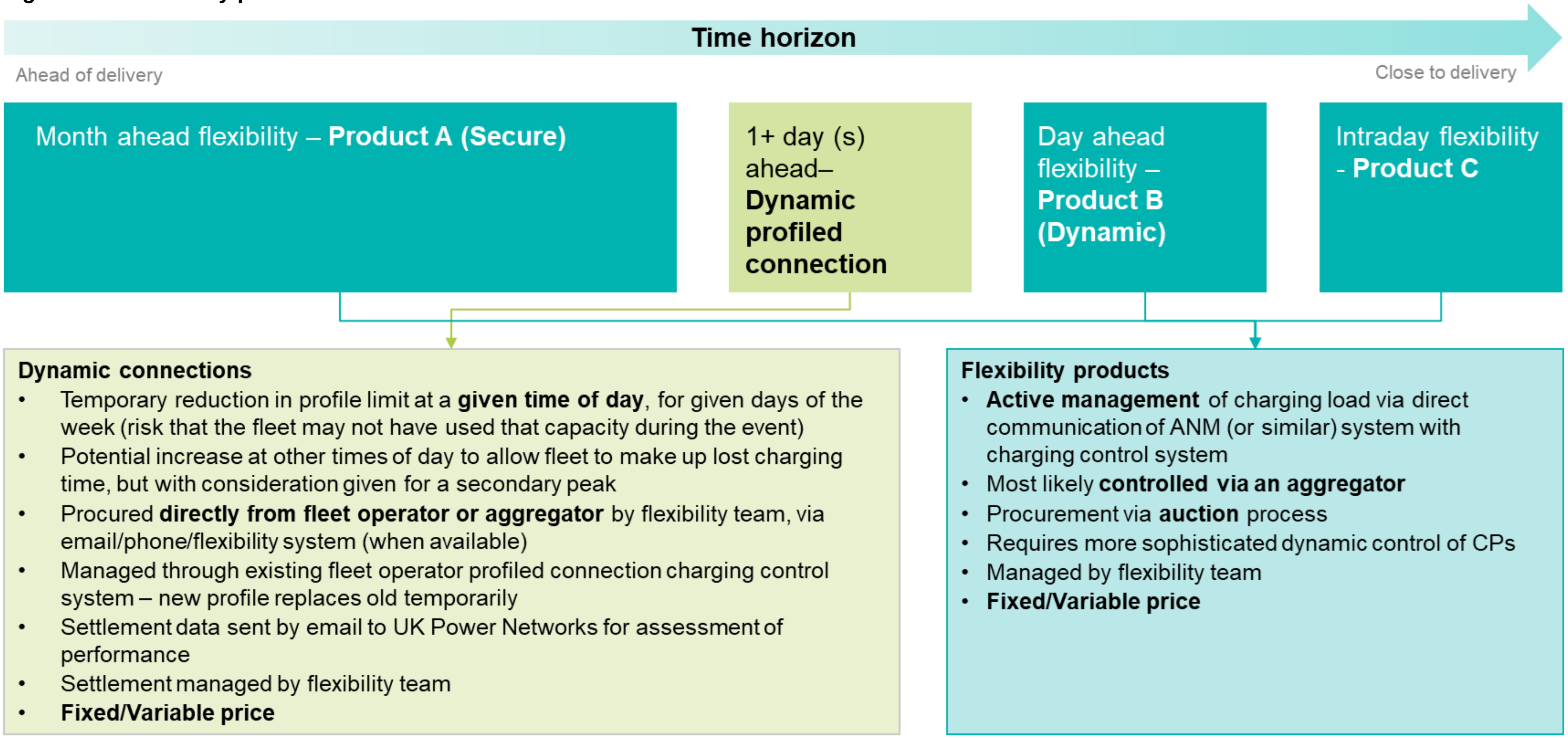
[4] Note that DNO Services are not formally part of the Electricity Market Reform's list of Registered Balancing Services, as a result there is some risk involved in stacking with Capacity Market obligations

2.1.4.3 Recommendations for implementation of Method 1: Flexibility Services by UK Power Networks and GB DNOs

Low participation in flexibility is not beneficial to the DNOs. DNOs need to consider how to incentivise more providers, including fleets, to provide a greater quantum of demand response. Flexibility products should reward a wider range of loads, both predictable and un-predictable, with the prices paid being commensurate to the value of the flexibility.

To achieve this, Optimise Prime recommends that DNOs develop multiple products to allow more customers to provide flexibility and increase the volume of flexible demand that is available. Figure 30, shows an example of the range of products that could be offered, based on those trialled in the project, together with key features of the different product types.

Figure 30 – Flexibility product time horizon



- In **longer horizon** (month, or year ahead) products, the value of utilisation, availability and success thresholds should vary according to how predictable a fleet's load is. This will have the benefit of ensuring as much turndown, from as wide a range of fleets as possible can be procured. Agreeing multi-year flexibility contracts may not be the most appropriate way of accessing the most flexibility capacity from these home and depot fleets, as routines and fleets can change over time. Consideration should be given to revising the forecast (which may have been submitted one month or more ahead of delivery) every week until delivery to improve certainty. The price could be locked in ahead of time, but the delivery volume flexible until a week, or day ahead, to give the DNO greater certainty over what will be delivered and whether shorter horizon products are needed. Longer horizon products could include a form of profiled, or dynamic connection agreement – this provides a potentially simpler route for fleets to participate in flexibility and is explored further in Section 2.1.5.

- In **shorter horizon** i.e., day ahead/Intraday: the value of the utilisation payment needs to consider other flexibility markets (e.g., the TSO market) to ensure that turndown is still provided where required in the LV network, as well as the HV network level. Whether intraday flexibility is needed will depend on the specific requirements of the DNO.

Table 15 sets out the proposed products for consideration:

Table 15 – Summary of flexibility types

Product	Network constraint type	Notice horizon	EV load turndown predictability	Price paid for turndown
Dynamic connection	Enduring – in place for weeks or months	One week+	High (60+%)	High
Long horizon flexibility	Sporadic over an extended period	One month	High (60+%)	Availability – high Utilisation – high
			Low (<60%)	Availability – low or none Utilisation – high
Short horizon flexibility	Temporary but known in advance	Day ahead	High (60+%)	High
			Low (<60%)	Low
Near real time flexibility	Instantaneous	Hours	High (60+%)	High
			Low (<60%)	Low

In order to categorise the turndown predictability, the DNO needs to set eligibility criteria for each product. Based on the trials carried out, the factors listed in Table 16 are likely to impact on the ability to provide flexibility reliably and predictably.

Table 16 – Factors impacting predictability of flexibility

Factor	Impact on response
Size of depot/aggregated group	Larger groups provide a more reliable response
Average daily distance travelled by EVs	The longer the journeys, the longer and more regular the charging session, and the higher the chance that there is load that can be curtailed.

Factor	Impact on response
Ratio of vehicles to CPs	1:1 EV to CP ratios make it simpler to predict when EVs will charge, even if utilisation of the CP may be lower
Regularity of shift patterns	Regular shifts and vehicle return times provide greater certainty that load can be curtailed
Seasonal nature of business	While seasonal business can provide reliable flexibility, the magnitude and timing will shift over time, and so this type of fleet may be less suitable to long-term products

Further to this, the following general recommendations are made to improve flexibility response and participation across all products:

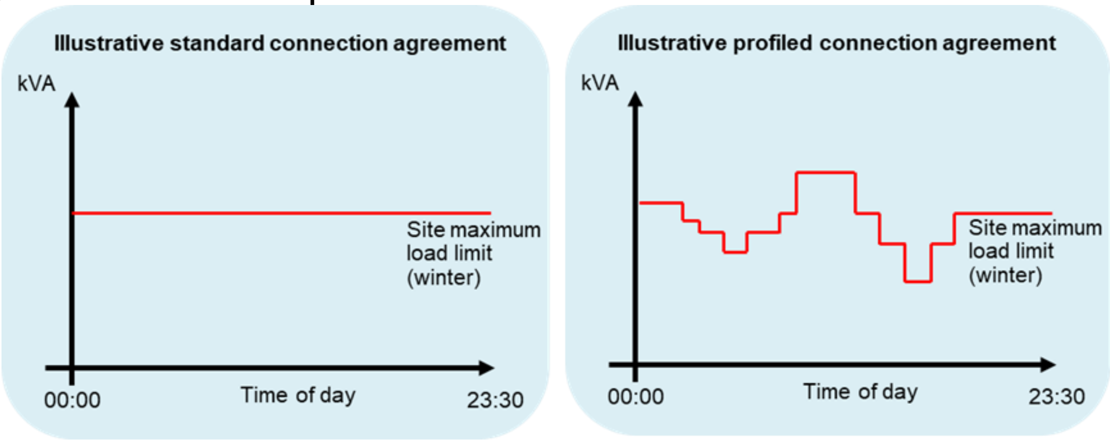
- Products should allow different bids for each day of the week
- Bids should allow for a different level of response in each half-hour period, rather than a single bid for a longer period, to account for the variable nature of EV loads
- Longer-term products should provide the opportunity for fleets to update their forecast load/turndown to give the DNO greater visibility of the likely success of the flexibility request
- Where baselining is needed it should not aggregate across different days of the week, and should be limited to the last two qualifying days
- Consider rewarding over-performance in some way to balance out variability in baseline reliability
- The potential impact of secondary peaks must be considered when procuring EV flexibility, potential solutions could include:
    - Scheduling the time when providers can ramp up as part of the bid or baseline
    - Scheduling additional flexibility to offset the secondary peak
    - Distributing the dispatch of flexibility services over time, or not fully dispatching all capacity at once, so multiple providers do not ramp up simultaneously
    - Managing maximum load through a profiled or other dynamic connection.

These factors should be considered as UK Power Networks and other DNOs specify the flexibility products that they bring to market for commercial fleets.

2.1.5 Mitigating peak load from EVs – Method 2: Profiled Connections

Profiled connections are a new type of flexibility product that is designed to allow sites to connect additional capacity to the network without triggering reinforcement by agreeing to limit load at specific times of day. The maximum load profile can be as granular as up to every 30 minutes, as shown in Figure 31. Sites can maintain this profile through active control of assets such as CPs. With profiled connections, fleets can potentially benefit from cheaper and quicker connection upgrades, because it may not be necessary to wait for physical upgrades to take place. Other network customers can also benefit, as the DNO is able to offer the connection while deferring reinforcement of shared network assets through more efficient use of existing network capacity.

Figure 31 – Illustration of a profiled connection



2.1.5.1 Site planning tool and UK Power Networks profiled connection modelling

When electrifying a fleet there are several options, including using public infrastructure, and letting drivers charge at home. For depot-based fleets it is likely that it will be necessary to install CPs within the depot. If the depot does not have sufficient existing connection capacity to accommodate EV charging, additional capacity must be requested from the DNO. Fleet operators are likely to request connection upgrades based on a worst case scenario of all CPs charging simultaneously at full rate, at the time background load is highest. Early analysis of the Royal Mail diesel fleet, considering 20 depots across south-east England, indicated an average cost of connection upgrades of up to nearly £100,000, for an un-managed charging fleet. Modelling indicated, however, that connection costs could be reduced significantly, and in many cases to zero, through the use of a smart charging regime that smooths out demand from the plug-in event to times when the site's background load is lower.

Based on this initial analysis of the Royal Mail fleet, Optimise Prime developed the Site Planning Tool (https://www.ukpowernetworks.co.uk/optimise-prime/site-planning-tool-introduction) to allow other depot-based fleets (or any other customers planning the install multiple CPs at a site) to optimise their energy requirements, understand the benefits they can get from smart charging and create an informed connection request to their DNO based on real load data and future demand predictions. UK Power Networks has developed a complementary capability to process time-profiled connection requests. The wider profiled connection process may also be suitable for customers connecting with other types of loads that are predictable or controllable.

2.1.5.2 Benefits for the network

For the DNO, and network customers as a whole, there are potential savings. Encouraging customers to request connection limits that more closely match their requirements (using the Site Planning Tool) can help streamline processes and better utilise capacity, while profiled connections can help more customers to electrify before costly upgrade work needs to take place.

The benefit of profiled connections in terms of network upgrades was estimated for the whole UK Power Networks area based on the load curve of a Royal Mail site participating in a profiled connection. Against the unmanaged charging scenario this resulted in savings in future network reinforcement, as discussed in Section 2.1.2.3. It must however be considered that the primary benefit of profiled connections is to overcome localised network constraints, and a variety of different profiles would be expected to be needed. Therefore, a network-wide analysis based on a single profiled connection shape may not show the full benefit of the method.

2.1.5.3 The results of the trials

As described in Deliverable D5, profiled connections were initially trialled at all nine Royal Mail depots. It quickly became clear that not all depots were suitable for this type of connection, because the EV load was not able to counteract large changes in background demand. Initial load profiles calculated based on telematics data were also found not to be fully accurate in estimating the timing of EV load, because EVs did not always plug in as soon as they returned to the depot. In more recent trials, profiled connections focussed on depots with a greater proportion of controllable load and profiles were re-calculated, based on the load that had been observed at the site.

This resulted in a greatly reduced frequency and size of breaches, with an average breach size of 6.06kW (compared with a profile that averaged approximately 92kVA). Where breaches of the connection did occur, they were generally short in duration:

- 50% breaches lasted for no longer than two minutes
- 75% breaches lasted for no longer than four minutes
- There were very few breaches lasting longer than 10 minutes

Where larger breaches, relative to the agreed profile, did occur, they were predominantly at times when EVs were not charging, such as late on Sunday nights or early on weekday mornings.

When setting the profiled connection, the DNO needs to consider whether there is a maximum size, frequency or length of breach that can be tolerated without causing disruption to other customers.

A further revision of the profiles, based on additional data gathered, was made in May 2022. This resulted in a significantly reduced breach rate: each breach averaging 2kW and lasting one and a half minutes, with the longest breaches much reduced as shown in Table 17.

Table 17 – Profiled connection results, May 2022

Week	Breach rate (%)	Maximum absolute breach (kW)	Maximum relative breach (%)
9-15 May	0.19%	4.9 kW (reading: 119.4 kW, profile: 114.5 kW) Wednesday, 12:57, duration: 2 mins	4.33% (reading: 102.6 kW, profile: 98.4 kW) Monday, 23:03, duration: 2 mins
16-22 May	0.23%	6.1 kW (reading: 101.7 kW, profile: 95.6 kW) Sunday, 23:12, duration: 5 mins	6.29% (reading: 101.7 kW, profile: 95.6 kW) Sunday, 23:12, duration: 5 mins

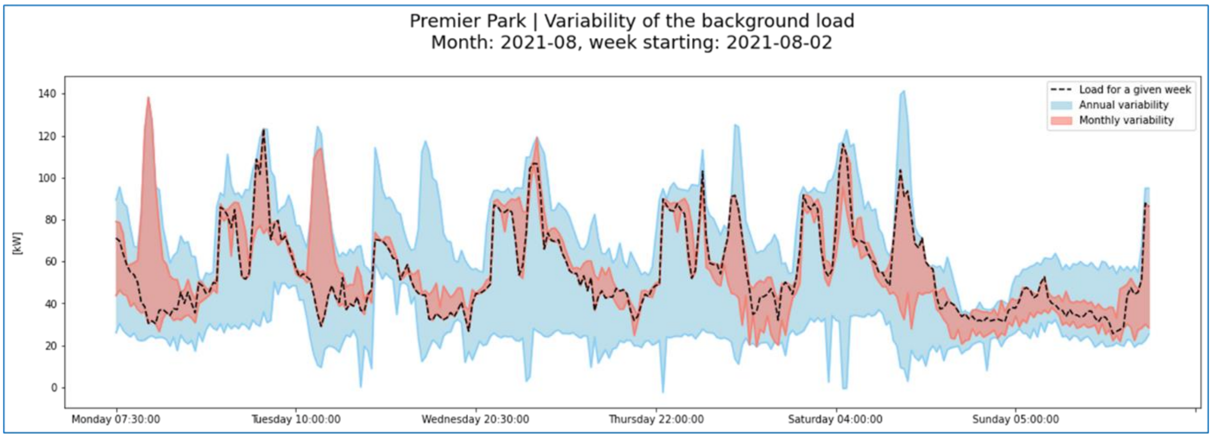
Further details of the profiled connections trials can be found in Appendix 1.

2.1.5.4 Insights

EV load must be the dominant load in the depot for the EV to be used to control load and to reliably ensure compliance with a profiled connection

The profiled connection trials showed that if the EV load was less than 50% of the variation of background depot load, controlling the EV load was irrelevant: the profile would eventually be breached unless the profile was set with sufficient headroom to accommodate the variability in background load, in which case no throttling of EV charging load would occur. Background load at sites was found to be extremely variable, as shown in Figure 32.

Figure 32 – Variability of background load, week vs month vs year



Therefore, for it to be possible for control of EV load to keep a site in line with a profiled connection, the site must adhere to a specific set of characteristics. The difference between the maximum building load (BL) (with a 10% margin for error added) and the minimum building load, over a forecasting period of at least two months of building load, must be less than the EV load:

$$EV\ Load < (Max(BL) * 1.1) - Min(BL)$$

While profiled connections were initially trialled at all sites, it was found that the majority of the Royal Mail depots did not meet this test, having a relatively high and variable background load. One site, with relatively high peak EV demand was selected as best meeting these requirements and trials of profiled connections were focused on this site.

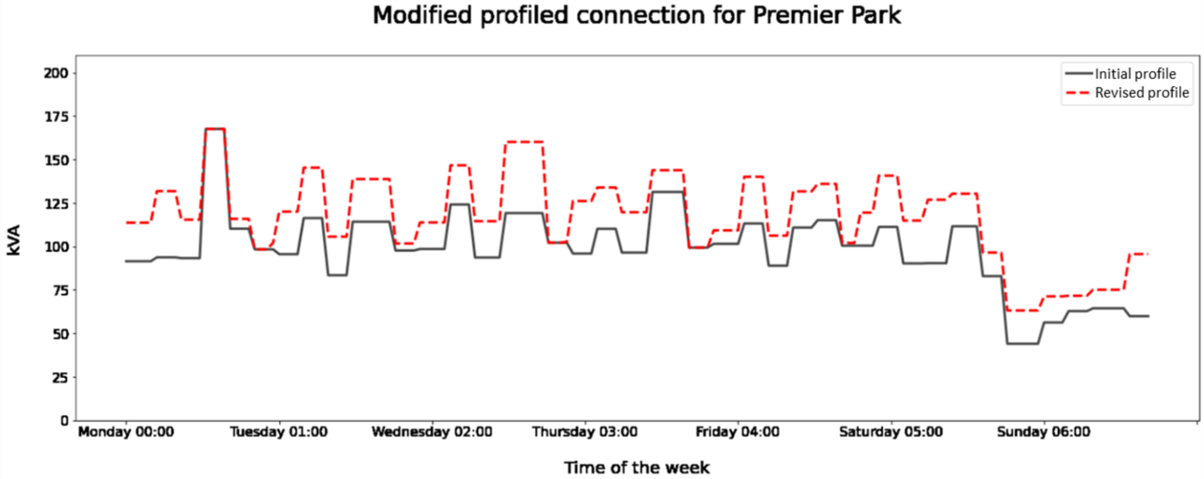
In short, the EV load must be the ‘dominant’ load in the depot for a profiled connection to affect EV charging behaviour and not result in profile breaches.

While ICEV schedules can be used to calculate total charging load, they are not sufficient to predict exactly when charging will take place

The initial trials established charging profiles based on the ICEV schedules (which have been seen to be a good proxy for EV schedules) where an assumption was made that when an EV returns to the depot, it will be charged immediately. This, together with the variation in background load, resulted in significant breaches – in the most extreme case this resulted in a profile being breached by up to 28%, 17% of the time, while one depot recorded a breach of 72% of the profile. Over time, such poor performance may cause infrastructure to fail or reduce its operating life expectancy.

The profiles applied to each depot were refined three times, based on more EV charging data becoming available, to the point where very few breaches were recorded. To achieve this, the profile had to be increased at specific times based on observed load, as shown in Figure 33.

Figure 33 – Modified profiled connection at Premier Park over a week

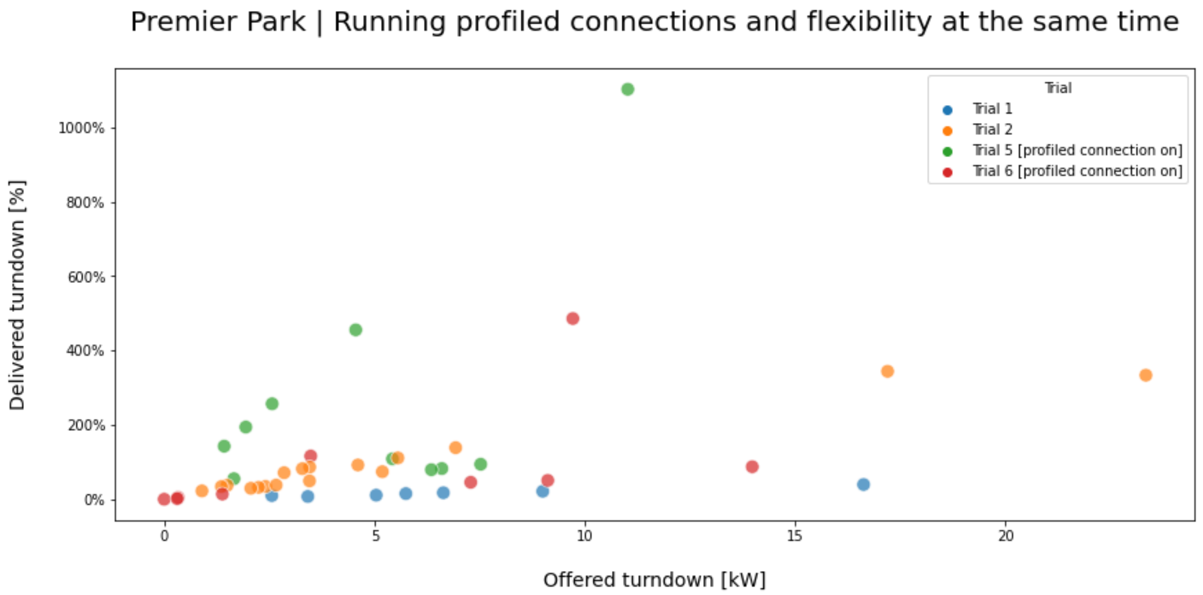


Profiled connections can be combined with flexibility services, but the profile may limit the response, and will need to have sufficient capacity for the provider to flexibility back up

Flexibility services were offered at Premier Park with and without a profiled connection being enabled. Figure 34 shows the result from these trials. For the trials where flexibility was offered on top of profiled connections, performance against the bid amount was not significantly worse than in trials without profiled connections.

The presence of a profiled connection can reduce the size of the bid that can be made, either because of properties of the site's load, the profile supressing load at the time flexibility is required or there being insufficient space in the profile to shift the load. This example does however show that there are scenarios when stacking the methods is possible.

Figure 34 – Flexibility results with profiled connections



2.1.5.5 Recommendations for implementation of Method 2: Profiled Connections by UK Power Networks and GB DNOs

The aim of a profiled connection is to allow more EVs to be connected to the network without triggering additional network reinforcement. The trials have shown that while profiled connections can work, there are certain limitations to their applicability. The profile needs to be carefully considered and will likely need to be revised over time; processes will need to be put in place by the fleet and the DNO to ensure the connection limit is complied with. The following section details the project's recommendations for DNOs considering implementing profiled connections for EV load.

2.1.5.6 Planning process and data requirements

2.1.5.6.1 Setting the profiled connection

A profiled connection application, using the site planning tool, is a more involved process for both the fleet manager and the DNO's connection team. Once the customer has calculated their capacity requirements using the Site Planning Tool it is recommended that a three-stage process to assess applications, as shown in Figure 35.

Figure 35 – Profiled connection application process

Stage 0: Site Planning Tool	Stage 1: Application review *2 weeks*	Stage 2: Load flow modelling *3 weeks*	Stage 3: Initial offer and iteration *8 weeks*
• Customer gathers required data and enters into Site Planning Tool	• Customer requests profiled connection based on site planning tool outcome • UK Power Networks team review application and confirm all necessary data has been provided	• UK Power Networks team reviews LV substation monitoring data and assesses available headroom by time of day • For LV substations without monitoring, proxy load assessment is done • Proposed profile with price estimate developed • Budgetary price estimate for firm connection prepared for comparison	• Profile and draft contractual terms shared with customer for review • Customer has opportunity to request changes, UK Power Networks responds with new offer (for example at a connection workshop) • Process can be repeated at customer request • Final offer agreed and contracts signed
Requirements calculated	Confirmation of profiled connection application started	Draft profiled connection ready for customer review	Final profiled connection contract agreed

1. **Submission and application review** – Customers provide the data and the DNO confirms the necessary data has been provided.
2. **Load flow modelling**
   a. the DNO reviews LV substation monitoring data and assesses available headroom by time of day
   b. For LV substations without monitoring, proxy load assessment is done, using LV utilisation modelled data, supplemented with HH data and/or NHH diversity modelling
   c. Proposed profile developed
   d. Budgetary estimate for firm connection prepared
3. **Initial offer and iteration**
   a. Profile and draft contractual terms shared with customer for review
   b. The customer has the opportunity to request changes; UK Power Networks responds with new offer (for example at a connection surgery)
   c. The process can be repeated at the customer's request. A depot manager will know the EVs schedules when applying for a Profile Connection, sufficient headroom or contingency will need to be factored in to avoid breaching a capacity limit. After a period of two months, by using the actual charging data, a profiled connection could be refined to enable more capacity to be released to other network customers or capacity to be requested from the network (which might be managed by flexibility

services where other network users release capacity at that time, e.g., through UK Power Networks' capacity exchange). This process may be repeated across the seasons (EVs requiring more capacity during winter).

d. Final offer agreed and contracts signed

2.1.5.6.2 Policing the profiled connection

It is important that customers keep within the agreed limits of the connection, otherwise risk to the network's stability may occur, especially if profiled connections are implemented on a large scale.

To police a profiled connection, processes and technology will need to be put in place to manage the connection. Three options are proposed:

1. Physical disconnection

The customer connects their EV load to a dedicated circuit breaker.

Load is actively monitored via an onsite DNO monitoring device, smart meter or HH meter, connected to the DNO capacity tool. In the event of profile breach, if the customer does not reduce load after three warning signals, EV load on the dedicated circuit breaker is disconnected via a trip signal from the DNO Active Network Management (ANM) systems through the DNO substation remote terminal unit (RTU).

In the event of loss of communications between site load monitoring and UK Power Networks, EV load on the dedicated circuit breaker is disconnected via the substation RTU. Following disconnection, either due to a breach or communications loss, it is then the responsibility of the customer to re-connect the load after ensuring the issue has been resolved.

The benefit to the DNO is the assurance of network integrity; for the fleet it is the avoidance of financial penalties.

The disadvantage for the DNO is the requirement to install and monitor the load monitoring device, and manage the communications process with the site fleet manager. For the fleet, it is the increased set up cost of separating EV load from other site load, and installing a dedicate circuit breaker with connection to the DNO monitoring tool, and the risk to operations from potential disconnection – in the event of disconnection, it is possible that no vehicles would receive sufficient charge for their next day's operations, as after re-connection, there will be less time left for the vehicles to charge.

For each network connection, the DNO would need to assess the appropriate thresholds for alerts and configuration for the automatic disconnection. The site manager would be responsible for ensuring the site is re-energised (i.e., circuit breaker is restored).

2. Economic penalties

Load is actively monitored via an onsite DNO monitoring device, smart meter or half-hourly (HH) meter, connected to UK Power Networks' capacity tool. In the event of profile breach, if the customer does not reduce load after three warning signals, an economic penalty is imposed by UK Power Networks. In the event of loss of communications between site load monitoring and UK Power Networks, an economic penalty is imposed by UK Power Networks unless the customer can demonstrate via historical data shared with UK Power Networks that EV load was operating within profile limits.

This option would not require separation of EV load, or the installation of a circuit breaker connected to the DNO monitoring tool to put the customer's EV load in failsafe state.

For each network connection, the DNO would install load monitoring and assess the appropriate thresholds for a breach and what level of communication loss is acceptable. The level of economic penalties would need to be analysed and reflected in the agreement with the customer. The DNO could investigate if a statistical breach probability approach could be developed to manage risk across multiple connection customers.

3. Hybrid

A hybrid approach could be developed for large and small EV load customers. For large loads only, customers need to have their EV load on a dedicated circuit breaker and breaches will be managed as per physical disconnection approach. A large load communications loss would be managed as per economic penalty approach.

All other customers would be managed as per economic penalty approach (for both profile breaches and communication loss).

The benefits would be to ensure that larger loads can be disconnected and that smaller sites would not have to install a dedicated circuit breaker, lowering the risk of a disconnection. The disadvantages are that the DNO would still need to administer fines as well as managing disconnection via the monitoring tool, and the fleets would either risk disconnection (for larger sites) or penalties (for larger and smaller sites).

2.1.5.7 Temporary profiled connections as flexibility product

DNOs should consider temporary variations to profiled connections agreed months or weeks ahead of need, to allow the DNO to buy back capacity as and when it is needed. This would allow fleets to sell excess capacity and could be extended to enable them to also buy temporary capacity.

This may encourage fleets who may not yet be active in the flexibility markets to participate in demand side response, without needing to calculate baselines or integrate external control signals. If a fleet operator has an existing charging control system (to ensure they do not exceed their connection agreement), then the new profile could simply replace the old one. A fixed price could further simplify participation.

This should also include customers with non-EV static loads. If these customers were incentivised to release unused capacity, it would provide additional unallocated headroom at shared network assets that could be taken up by the EV charging load of other customers. Customers who are not facing a specific constraint could also be encouraged to adopt a profiled connection in the long term if it suits their demand pattern, in return for an incentive. This could provide benefit to the network and help in accommodating future customers on existing infrastructure. While the DNO could be a counterparty to these transactions, there may also be benefit in the DNO simply facilitating temporary transfers of connection between customers – in instances where Customer A temporarily needs more capacity and Customer B can commit to using less than their allocated capacity.

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

The value proposition for smart solutions for EV fleet and PHV operators in the project comes from three elements, broadly aligned with the methods trialled in the project:

1. **Flexibility services**: Utilising the ability of fleets to change when they charge their vehicles, in respond to signals from the DNO, in return for financial compensation.

2. **Profiled connection**: Agreeing a variable connection capacity limit with the DNO that can reduce the capital expenditure and time needed to install multiple chargers on a site. This applies to depot-based fleets, but not to home-based fleets.

3. **Time-of-Use tariff based smart charging**: Reduction in operating costs of fuelling an EV fleet by ensuring the charging activity is performed at the time of cheapest (and lowest carbon intensity) energy. Smart charging can also be applied to reduce the capital expenditure (CAPEX) on an electricity connection upgrade when the overall load can be managed below a traditional firm site connection agreement, as described in Deliverable D5. Both of the above must be achieved while ensuring that the operational requirements of the vehicle are not impacted.

The value proposition for these specific services forms part of a wider TCO analysis that is carried out by fleets, comparing the financial benefits of electrification vs the continued use of an ICEV fleet. A summary of the project's TCO analysis can be found at the end of this section and a full version in Appendix 4.

2.2.1 Value proposition for smart solutions – smart charging

2.2.1.1 Home

While most domestic customers are on tariffs that have a fixed energy cost throughout the day, there are several time-of-use tariffs available with cheaper prices at off-peak times, typically between midnight and 7am. If these tariffs can be used either by the homeowner or corporate bill-payer then there is value to be gained from shifting the charge activity into the off-peak period. Given a standard Economy-7 tariff, which some British Gas engineers had at home, charging costs could be reduced by 50% per vehicle.

However, it is important to consider that this is unlikely to be applicable to the majority of drivers charging at home, because a tariff of this type can also increase the cost of electricity used during the day. Unless the driver already has such a tariff, they are unlikely to adopt one for the financial benefit of their employer, unless incentivised to do so.

2.2.1.2 Depot

Corporate energy bills typically have time-of-use tariffs built in to reflect the peak and off-peak times and also have network usage charges applied at specific times of day. Therefore, there is value to be gained from smart charging – the amount that can be saved can vary significantly depending on the tariff a company agrees with its supplier.

2.2.1.3 Mixed

Smart charging of the mixed trials fleet could not be tested because the CPs were not managed. It can be assumed that the off-shift charging at drivers' homes would have access to similar tariffs to the British Gas home-based drivers. However, as the average plug-in time for PHV drivers is later than that for British Gas drivers, there may be less overall benefit or less opportunity to shift charging closer to the start time of the next shift. Given that PHV drivers are also the energy bill payers, there is a higher incentive and fewer barriers to changing the domestic energy supply to a time-of-use tariff, and the driver may better manage the other impacts of this within the home.

2.2.2 Value proposition for smart solutions – flexibility services

The Optimise Prime trials have demonstrated the ability of EV fleets to provide flexibility services to the DNO and by extension also to the ESO. A nominal value was allocated to the flexibility derived from these trials, for the purposes of measurement within the project, and the project benchmarked this against market data to estimate the overall value proposition for EV Fleets participating in such markets.

2.2.2.1 Home

The reliability, albeit over a short window, of the home-based flexibility trials gives the project confidence that the value is worth exploring. Using published UK Power Networks figures for guideline flexibility revenues[5], it is estimated that £215 per vehicle, per year, could be earned from flexibility services, based on the vehicle being in an area with a requirement for flexibility services and 10% of bids being dispatched from the most favourable product. It should be noted that not all vehicles would be in an area with a demand for flexibility services and there would be a requirement for a provider to aggregate sufficient demand to make a bid.

The trial proved the reliability of timing of British Gas' home-based fleet schedules. However, the diversity of fleet operations will require a scaling factor when calculating potential revenue across the fleet, as a result the average per-vehicle revenue will be lower than indicated above.

2.2.2.2 Depot

Assessing the day-ahead flexibility product described in section 2.1.4, the project benchmarked the flexibility prices used in the project to market value using data on previously accepted DNO flexibility bids[6]. This resulted in a calculated rate of 55p/kWh. Following the same methodology in assessing the month ahead flexibility product, this resulted in a calculated utilisation rate of 33p/kWh and availability rate of 12p/kWh. It should be noted that these are historic prices from similar markets, and future revenue expectations may change as flexibility markets develop further. Because the Royal Mail depots had between one and three vehicles per CP, the value calculation is made on a per CP basis in this model, rather than per vehicle. It was assumed that 20% of any revenues would be consumed by the cost of delivery, for example the fees applied by an aggregator.

Assuming that the DNO requests 10% of the total flexibility a large (100 EVs) depot can deliver, and with 100% delivery performance, then over 260 active days per year a large depot could benefit from around £4,500 from participation in day-ahead flexibility after costs are subtracted, or £12,400 from participation in month ahead flexibility without any changes to

---

[5] https://smartgrid.ukpowernetworks.co.uk/wp-content/uploads/2022/04/Appendix-4-Revenue-Ranges-1.xlsx

[6] https://picloflex-static-public.s3.eu-west-2.amazonaws.com/landing_page/Piclo_Flex_Confirmed_Bids.xlsx, https://smartgrid.ukpowernetworks.co.uk/wp-content/uploads/2021/06/Flexibility-Post-Tender-Report-Bids-Feb-2021.xlsx

operations. This is equivalent to around 7% and 20% of the total depot energy bill for day ahead and month ahead respectively. The trials results, however, showed that delivery performance can vary and is dependent on multiple factors. For example, achieving 100% delivery performance occurred more often with day ahead flexibility product due to the load predictions happening closer to the dispatch time, making forecasting more reliable. Performance incentives in the month ahead product can also result in significant reduction in revenue if a minimum reliability of 60% cannot be achieved. More details about flexibility trials results can be found in Appendix 1.

2.2.3 Value proposition for smart solutions – Profiled Connection

The intention of the profiled connection is to save cost, both for the electricity bill payers and the connecting customer, while reducing time to connect for fleets looking to electrify, helping to accelerate their transition to EVs.

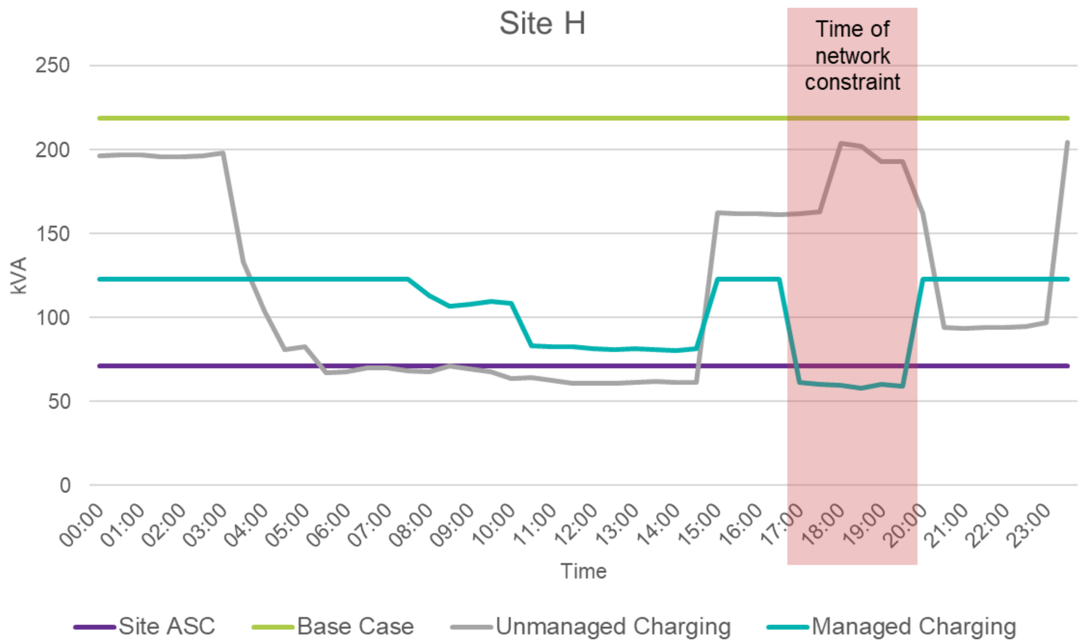
Analysis in 2019 of the Royal Mail diesel fleets, across 20 depots, indicated an average cost of connection at £100,000 for an un-managed charging fleet; this could be reduced to almost zero through the use of smart charging: moving demand from the plug-in event to after 21:00.

During the project, Ofgem announced the outcome of its Access and Forward-Looking Charges Significant Code Review. This will result in changes to how the cost element falls to the connecting customer from April 2023 onwards; costs for reinforcing shared network assets will now generally be socialised amongst all network customers through electricity bills, while connecting customers will only be responsible for extension assets, such as service cables and dedicated substations, if these are needed.

While the regulatory regime has changed some of the benefits for the connecting customer, the profiled connection should still speed up connection time. Time to connect can be a crucial factor – it may not be acceptable to wait months or years before a fleet can transition, and this uncertainty can add to the complexity of electrifying a fleet. Where companies are transitioning fleets over time, profiled connections could also be considered as an interim measure ahead of a firm connection upgrade.

In order to test the end-to-end process, the site planning tool was used to analyse the full electrification of a further eight Royal Mail depots in southeast England. The outcome of this analysis, in the form of predicted maximum load curves, was shared with UK Power Networks' connections team in order to calculate the cost and timeline for connection in a worst case base case scenario, an unmanaged charging scenario and a smart charging/peak load-minimised charging scenario. Profiles for three of the sites were further revised, in order to reduce demand around the network peak between 17:00 and 20:00 due to local network constraints, as shown in Figure 36.

Figure 36 – Example load curves from an electrified depot from the project site planning tool



Cost of connection for the base case (firm capacity covering the maximum load possible from all chargers, at peak background load time) amounted to up to £324,000 across the eight depots. Basing the connection on un-managed charging (considering when the vehicles would charge) reduced this to £221,000; and peak load minimised smart charging (avoiding network peak where necessary) reduced the cost to £41,000, with six of the eight depots not incurring a cost. The reduction in the amount of work needed to connect resulted in the estimated time to connect falling from 12-16 weeks to no more than five weeks. The main drive for reinforcement cost was sole-use asset replacement (service cables, cut-outs, private transformers, etc.) and the reduction in time to connect could be greater if the load were to have triggered upgrades further up the network.

2.2.4 Total Cost of Ownership

An understanding of the economics of fleet electrification is useful for DNOs and other stakeholders, as the cost-benefit analysis impacts upon how quickly fleets will electrify. The analysis can also help put network-related costs in context with other costs involved in electrification.

The initial outcome of TCO modelling was presented in Deliverable D5. The analysis has been updated to consider the potential financial benefits of the Project's methods to fleet operators, as well as recent changes in costs impacting upon fleets.

The full revised TCO analysis can be found in Appendix 4, while the following section highlights some of the key changes to assumptions and findings.

2.2.4.1 Updated assumptions

During 2022 there has been significant movement in fuel and electricity prices, which has a high impact upon the outcome of TCO analysis. The high volatility and therefore unpredictability of market prices together with the changing government support for homes and businesses makes it particularly difficult to establish accurate long-term TCO models. As a result, several scenarios have been created for comparison of steady vs. volatile prices or a

2021 vs. 2022 view and some of the main model assumptions have had to be updated as follows:

- The average annual electricity price used for the model base year in 2022 is at least 50% higher than used in the 2021 starting year in Deliverable D5. For future years, typically over an eight-year model and after any proposed Government support packages expire, an energy wholesale price forecast from analysts Cornwall Insight has been used to apply a percentage yearly change in electricity cost. The same approach has been used to estimate future public charging prices. The model used for Deliverable D5 applied the rate of inflation to energy and charging costs.
- The rate of inflation has also risen significantly, and so an updated average annual rate has been used for 2022, and a Bank of England forecast used for future years where available. For the years beyond the forecast, the assumption is the government target of 2% will apply. Inflation applies to costs such as maintenance, insurance, etc. but not to electricity, fuel or the cost of vehicle lease agreements.
- Average annual fuel prices from UK government sources have been used for the model base years and a flat rate 5% increase used for the predicted change in future prices, which is based on the average increase in fuel prices over the last 20 years.
- Project figures for fleet mileage and vehicle efficiency have been used to model a specific scenario for the Optimise Prime trial fleets. These figures are based on actual journeys recorded in the project's systems and therefore provide a real-life view and are representative of the project location, i.e., for Royal Mail, these are London-based depots with potentially shorter daily mileage than a national fleet. Therefore, a generic scenario with national average vehicle inputs for depot-based fleets is also presented in Appendix 4.

2.2.4.2 Key findings

The key findings from the TCO analysis include:

2.2.4.2.1 Home-based fleets

Comparing a home based ICEV fleet with a similar scale to the British Gas fleet to an equivalent EV fleet with updated fuel and energy costs, the EV fleet is expected to be £139 million or almost 25% more expensive than the ICEV fleet over the course of eight years.

The primary cause comes from higher EV lease costs. When using forecasted EV fleet charging costs compared with diesel costs the model shows that EV operational costs are expected to reach parity with ICEV by the year 2025 at a cost of £22 million per year.

The project also modelled a direct vehicle comparison. A single EV, charging at home, is expected to be £10.8k more expensive than an ICEV over the course of eight years. Charging on a public charge point makes the EV £22k more expensive than an ICEV after eight years.

Based on the flexibility trials conducted by Centrica, and mid-2022 prices, the project predicts that revenues of £817k per year could be possible if 50% of the fleet (4,750 vehicles) participated in flexibility services, offsetting £8m of operational costs over the life of the fleet.

2.2.4.2.2 Depot-based fleets

In the Base Case for the depot-based fleet monitored in the project, the TCO model shows that over eight years the cumulative costs of a fully electrified fleet are cheaper than an ICEV fleet in all price scenarios by an average of £3.6m or 9% of the total costs. This is despite the CAPEX costs of EVs being higher than equivalent ICEVs and despite the increase in electricity costs in the early years of the model. The forecast used suggests the wholesale price of energy will fall from 2023, whereas it is assumed that diesel costs will rise by an average of 5%, per year, based on historic market price increases.

Smart charging is utilised to reduce connection costs by controlling peak demand, simulating the use of a profiled connection. Through a desktop study it was found that connection upgrade costs could be reduced by between £2,000 and £45,000 per depot by reducing peak power consumption. Based on this, the financial benefit across the nine depots of transitioning to EV is increased by 21% (on a net present value basis) because of lower connection costs. Further savings could potentially be made by also smart charging to a time-of-use tariff.

Trials of flexibility services across the Royal Mail depot-based fleet suggest that between 7 and 20% of fleet charging costs could be covered by revenue earned from participating in DNO flexibility markets. Results from the month-ahead flexibility product (Product A) demonstrated that up to 2% of overall operational costs for the electric fleet could be covered by revenue from successful turndown of 20% of the fleet if 10% of bids were to be dispatched by the DNO, based on market benchmark prices for flexibility.

2.2.4.2.3 Private Hire Vehicles

Uber drivers have more choice of vehicle than the home or depot fleet when switching from an ICEV to an EV and so the project created a range of personas to compare the economics of either buying or leasing, charging at home or on public chargers and even buying a second-hand EV when compared to running an ICEV. Considering a range of options is important as some choices, such as buying a new vehicle outright or purchasing a second-hand EV, may not be available to many drivers due to upfront cost and the very limited supply of used EVs. These drivers may have to choose a leased vehicle even if the TCO is not optimal.

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 16% lower, despite the initial CAPEX being 40% higher. The higher CAPEX is offset by savings in London congestion charges and running costs, resulting in a payback of two to three years after which lower OPEX of the EV makes the TCO in the following years cheaper when compared to an ICEV.

Public charging reduces the TCO gap between ICEV and EV regardless of the financing option, but the EV still ends up cheaper over five years. However, factoring in an estimate of 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 the EV if the public charging takes place when the driver could otherwise be working. As the majority of PHV drivers in London will not have off-street parking, this highlights the need for public charging infrastructure that is near to drivers' homes. This allows charging to happen overnight, avoiding the opportunity cost and price premium of rapid charging.

In the leased vehicle scenario, there is a £9k saving for an EV compared with a leased ICEV with a five-year, because of the avoided congestion charge and lower fuelling costs offsetting the higher annual lease costs. The TCO of a used-EV is £16k lower than a second-hand ICEV because of lower maintenance, insurance and tax adding to the EV benefits.

Avoidance of the congestion charge in London is an important element of the TCO calculation, with 75% of shifts modelled as entering the congestion charging zone. It should be noted that PHV drivers outside of London will generally not realise this benefit and will have to consider this in TCO calculations, while London EV drivers will not be eligible for the congestion charge exemption from December 2025.

2.2.4.2.4 Summary

The results have highlighted that, at the present time, the financial case for EVs varies significantly by type of fleet and use-case.

Over 100 input parameters were used to generate a TCO across the three fleets and the project updated the inputs several times during the project, including a forecast of future costs, to model how the business case might change. For example, the project found that the operating costs for a depot-based EV fleet could increase by over 8%, from 2021 to 2023, due to electricity cost rises. For a single PHV in 2021, the potential increase in operating costs could be up to 20%, to 2023, and home-based fleet could be facing an 88% increase in domestic electricity costs when comparing the average tariff, in 2021, to that expected in 2023, even with government intervention.

Fuel prices for ICEV also fluctuated over the course of the project, particularly in 2022, but increases in diesel or petrol costs were not as large as for electricity (~50% increase between 2021 and 2022 compared with 100% for electricity). Therefore, the reduction in the OPEX component of the TCO for EV compared with ICEV became smaller.

In all fleets, an EV currently costs more than its ICEV equivalent whether purchased outright or leased, although the extent does vary by type of vehicle. The home-based fleet would need to see a reduction in the lease price of between 20%-30% from 2021 prices for EV to be competitive compared with ICEV TCO. When adding the increased electricity costs, in 2022 and 2023, lease costs would need to fall by 30-40% to reach TCO parity, with ICEV, in this period.

While it is anticipated that the price of EVs will continue to fall, price declines have been limited during the project due to supply chain constraints, as even with the limited financial incentives, business demand is exceeding the supply of commercial EVs. This is likely to continue for the foreseeable future, as fleets consider reputational and environmental aspects, as well as costs, in their procurement decisions. Policy impacts, such as the ban on the sale of new ICEVs, from 2030, also impact decision making.

2.2.5 Behavioural findings

Financial motivators are not the only value consideration when fleets choose to switch their fleets to EV. Environmental and reputational benefits are a key consideration, as is ensuring that business can carry on as usual and that drivers are happy with their new working environment. Optimise Prime explored behavioural aspects of the transition to EV by conducting over 3,000 surveys of vehicle drivers and fleet managers. The surveys included 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. The survey process was repeated during the project to identify trends. The results of the survey not only raise learning points for fleets looking to electrify, but also factors that may accelerate or slow the overall transition and the resultant impact on the distribution network. The full results can be found in Appendix 5.

The initial results of the behavioural surveys were presented in Deliverable D5, focused on the three trial partners. The project supplemented this work by surveying fleet customers of Novuna Vehicles Solutions. Overall, drivers have shown a positive reaction towards EVs, although some of the key issues across all fleets include the impracticality of long charging durations and accessibility to charge points, for both EV and non-EV drivers.

In the Royal Mail fleet, there was an increase in the difficulty to access charge points, because Royal Mail has begun sharing charge points between two or three vehicles.

The access to CPs was also a concern in British Gas' fleet. The reason is attributed to the roll-out of EVs outpacing that of CP installations, as well as the inability to install home chargers at certain homes because of physical limitations. Many drivers who are home based also rely on public charging infrastructure. Therefore, accessible rapid public charging is vital for those new EV drivers are unable to charge at home.

Concerns about limited range was also a perception amongst drivers. It was found that, on average, EV drivers who reported travelling the shortest distances were 17% more likely to view limited range as a high risk, compared with those drivers that travelled the greatest distances. This indicates that drivers who are less experienced may be more worried about range impacting their work, than those drivers who have been driving for longer, or who travel the furthest distances. Accordingly, range anxiety is likely to diminish as experience with EVs grow.

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. This appears to be improving, notably for British Gas, over the period the surveys were repeated. The project also found that EV performance is generally regarded as positive across all fleets. Most drivers recognise environmental benefits, acceleration and reduction in noise pollution, and many consider the social perceptions of EVs to be positive.

All results were compared to look for similarities using a methodology from Imperial College London. The project found that drivers who would recommend EVs to others report having a good experience with charging, acceptable charging duration and satisfactory range and are less concerned about the impact on their daily tasks from the switch to electric.

Conclusions were also drawn where those drivers who would not recommend EVs did not feel that the transition was supported by management and did not recognise environmental and cost-saving benefits to the organisation as much. This suggests that the change involved in transition efforts needs to be carefully managed, perhaps through increased training and support to ease concerns. Drivers that were not happy with their EVs had broader concerns over a range of technical, organisational, economic, and environmental aspects. This demonstrates that there are multiple areas to focus on with educating drivers.

On average, 84% of all drivers surveyed at least somewhat supported the expansion of EVs in their organisation, and once drivers had tried an EV they felt more positive about the technology.

In short, surveys concluded that behavioural factors were not a strong barrier to electrification. The project recommends that fleets should focus on improving the confidence of drivers, with training and clear procedures to follow.

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

Optimise Prime implemented and tested a range of infrastructure solutions to deliver the project's trials. The section provides an overview of the infrastructure that was put in place to implement the methods, detailing the findings made regarding the implementation of the trial infrastructure and systems and providing recommendations for the future implementation of EV charging solutions for fleets.

This section builds on the description of the solution build, install and commissioning phases that were published in Deliverables D2 and D3, and gives an overview of the key IT, equipment and practical considerations that are faced by fleets as they transition to EVs. To accompany this section, more details of what the project has learnt from implementing the project's infrastructure and systems can be found in Appendix 9.

2.3.1 Infrastructure requirements for fleet electrification

Optimise Prime built, tested and made use of a solution comprising of EV charge point hardware, DNO network tools, information feeds and IT systems to enable both fleets and the DNOs to transition their businesses to support EVs. Figure 37 illustrates the main infrastructure and IT which will be discussed below for the home and depot EV fleets.

The following sections consider the key considerations for fleets in the different stages in their electrification journey. A more detailed guide to electrification for fleets has been published by the project and can be found in Appendix 6 or on the UK Power Networks website.

2.3.1.1 Planning – pre-electrification

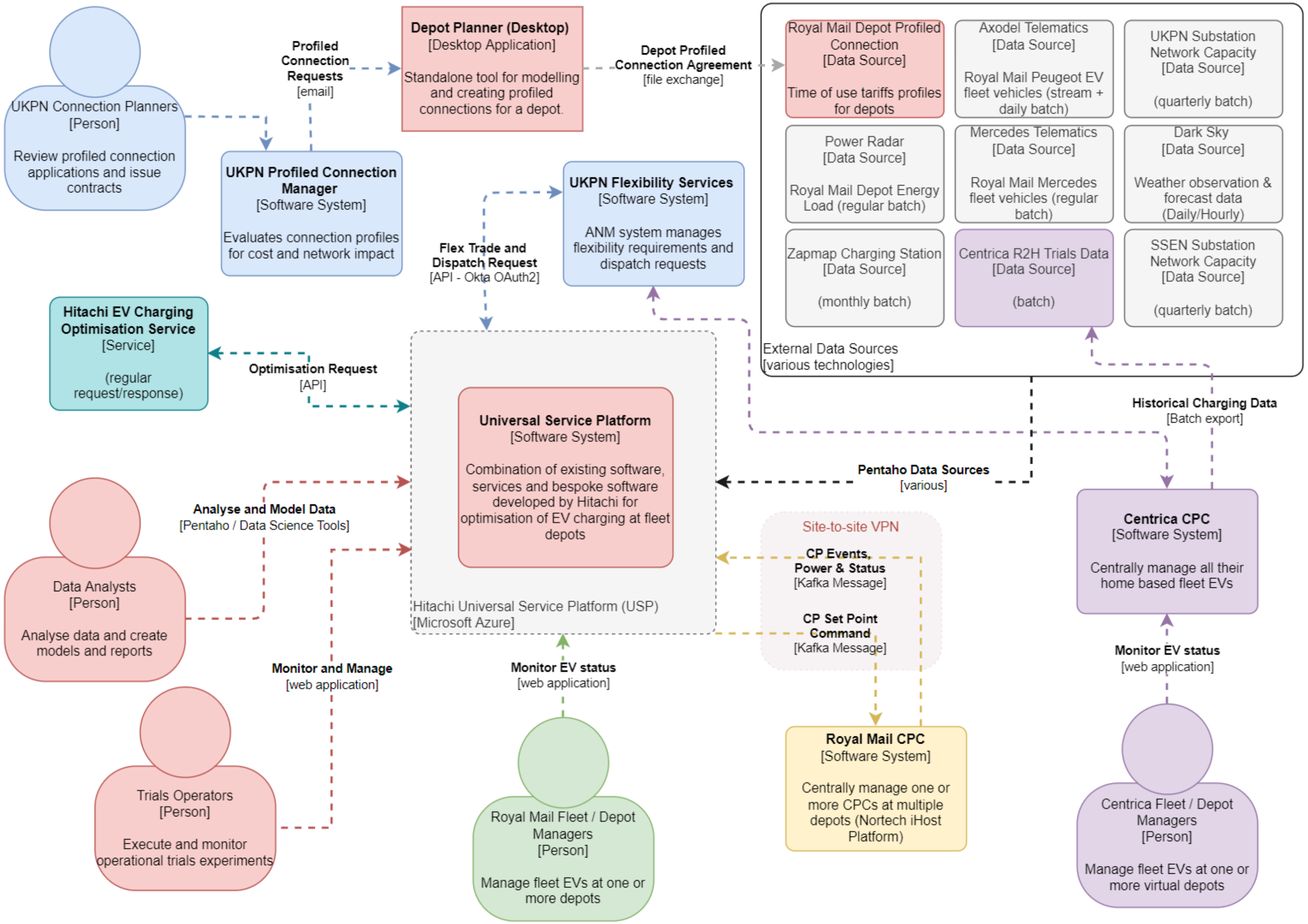
2.3.1.1.1 Home based fleets

When planning how to electrify a home-based fleet there are several key considerations for the fleet operator, for example:

CP feasibility – A fleet operator must ensure that a CP can be physically installed in an appropriate location at the driver's home. They must also assess the availability of spare electrical capacity at a driver's home by conducting a maximum demand calculation before installing a CP. To check whether the network connection is suitable at the driver's home, the CP installer can use UK Power Networks' Smart Connect tool. Smart Connect carries out an automated assessment of the connection. Where possible, it automatically approves the application, and the installer can proceed with CP connection. If there is a need to upgrade any equipment to accommodate the installation, the tool automatically refers the application to UK Power Networks' internal team and schedules a job.

Where it is not feasible to install home charging, the fleet operator will need to be made to ensure that there are public CPs convenient to the driver's location. Arrangements will need to be made to provide access to public charging (such as an account or payment method) and to provide the driver with sufficient time to charge their vehicle if it is necessary to do so on-shift. Drivers travelling longer distances may also require access to public charging.

Figure 37 – Infrastructure implemented in Optimise Prime



Telematics/operational schedules – A fleet operator must predict the amount of power required and when it is required, by assessing the daily mileages from the operational schedules, or derive from telematics data, which may be provided by the vehicle or from an aftermarket installation. The leave and return times can be derived from the telematics and this can be included in charging schedule. This information can be useful in planning budgets and is essential information if smart charging or flexibility services are to be used.

Electricity supply tariff – knowing what tariff the driver is on can, where the tariff has different price rates for different times of the day, be used to schedule charging at the cheaper times of the day, and therefore reduce the operational cost of the EV. A system would need to be in place to notify the fleet manager of changes in tariff. The fleet manager cannot direct the driver to adopt a specific tariff, and adopting such a tariff needs to be considered carefully by a driver, because it could impact upon the cost of their domestic electricity at other times.

Electricity expenses identification – All home chargers need to be metered in order for charging costs to be reimbursed. Fleet managers should consider how to link the EV to the CP to ensure that the electricity being claimed is for the business EV and not a private EV. One solution is to provide vehicle identification using telematics data, to a back-office system, which then reconciles the EV's location, and time of charging, with the CP location and time of charging, either systematically or as a periodical audit. Centrica implemented such a system and provided the ability for a British Gas driver to flag charging of a non-fleet vehicle. It is expected that as OCPP 2.1 and plug and charge capability becomes widespread this will simplify vehicle identification and reduce the need to reconcile multiple data sources.

Expenses re-imbursement – To be able to reimburse drivers for the electricity used to charge their vehicle at home. There are three options proposed:

i. Fleet managers can estimate the usage and set up a process to re-imburse the driver in advance of the electricity bill through their payroll. This was the original solution chosen by British Gas, however, 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 a disproportionate emphasis is placed on the events that are freshest in one's memory. Overcoming such perceptions may be difficult and require a significant communications effort

ii. The fleet operator sets up a process with a third party, where the third-party links to the home CP and pays the driver's electricity supplier directly, rather than the driver having to be part of the process. The third party then invoices the fleet for the electricity that has been settled with the supplier. This removes the bill shock scenario and may also reduce the administrative burden on the fleet operator.

iii. The fleet operator becomes the owner of a second MPAN, at the driver's home, and settles the electricity cost with its own supplier. A regulatory change would be required to allow a home to have a secondary meter on one fused cut-out. This is an area of innovation which would allow the use (and creation of) dual rate meters, with each rate attracting its own MPAN. This method would ensure that the load on the DNO supply cable remains the same as the standard domestic supply, with an EV charger, but allows for separated supply and energy billing, as per Option 2. In addition to allowing the fleet operator to settle their own electricity account, this option would allow the fleet to negotiate their own electricity rates and take advantage of time of use tariffs.

If a driver has solar PV installed at home, the system should also consider how to re-imburse the driver for the solar energy used to charge the EV.

2.3.1.1.2 Depot

In addition to the considerations of the electricity tariff, a fleet manager must plan for the required electrical capacity required at a depot and the Optimise Prime Site Planning Tool can be used to estimate whether or not the existing supply agreement can be used, or if additional capacity is required. The explanation of the Site Planning Tool is provided in Appendix 7. The following information will be needed to plan depot capacity requirements:

Building load – for depots with half-hourly metering, or a building management system, the building load for the past one to two years can be used to estimate when the peak power usage is, to enable a smart charging regime to be implemented around these times. If neither are available, an estimation using a standard profile, based on yearly total energy consumption, could be used, assuming 50% increase in power usage between 5p.m. and 8 p.m.

Telematics/operational schedules – to predict the amount of power required and when it is required, a fleet will either have to assess the daily mileages, from operational schedules, or derive the data from telematics system, which may be integral to the vehicle, or an aftermarket installation. The leave and return times can be derived from the telematics.

EV manufacturer data – Data on the proposed EV's range, efficiency, charging capability, battery size is required.

CP information – Data on proposed CPs to be installed on site to meet the proposed EV needs, this includes: number of CPs, number of sockets per CP, and the capacity of the CPs.

The data listed above can be entered into the SPT which will work out a power demand curve relative to a site's capacity (if it is an existing site), the site's load, and the required new EV load to meet business operations.

2.3.1.2 Operations – post electrification

2.3.1.2.1 Home

Charge points – depending on the available capacity at home, either a single phase 3.7 kW or 7.4 kW CP should be installed. The Electric Vehicles (Smart Charge Points) Regulations mandate that from 30 June 2022 all CPs should be smart in so far as to have the ability to automatically delay charging to start outside peak hours, with a randomised delay, which has the aim of reducing load on the network at peak times. If the fleet wishes to participate in smart charging or grid services, the CP should be controlled via a back office smart charging system rather than this automated smart charging control

Load balancing – the CP can be linked to a home energy monitoring device which balances the load of the home by constraining the charge point if the whole power consumption reaches a threshold (e.g., 100 amps fuse rating).

Smart control – a back-office system can be linked to the CP to provide charging schedules to make use of different rates, should a suitable tariff be available.

EV telematics – the EV telemetry can be integrated with a back-office optimisation system to support the settlement of energy used by confirming the fleet EV's location and time with the time of charging

Energy settlement – a meter reading is taken from the CP meter and used to settle the payment for electricity used by the fleet vehicle.

2.3.1.2.2 Depot

Charge points – depending on the available capacity at the depot, either a single or three phase 3.7-22 kW CP could be installed. Fewer higher capacity direct current chargers could be considered in cases where EVs are not parked for long period between shifts. The benefits of a higher capacity CP are if the ratio of EVs to CPs is greater than one, the EVs will be charged more quickly, provided the vehicle is able to charge at that speed. The CPs should be compliant with OCPP and be able to accept a charging profile.

Building load monitoring – in order to manage smart charging, the optimisation system will need to know what the electricity demand of the building is at any point in time. This is so that load balancing or profiled connections can be implemented. A device will need to be installed behind the meter – i.e., on the customer side of the connection – which will regularly feed the optimisation system with power values. If the building load increases, EV charging can then be dynamically constrained, such that the capacity limit for the site is not breached.

Smart control and optimisation – several different options exist for managing smart charging, depending on whether the fleet's priority is to reduce load, reduce operational costs, or ensure vehicles are all charged to a minimum level:

- **Load management** – a supply capacity (ASC) is specified for each depot under control. This should reflect the depot's connection agreement with the DNO. At all times, the optimisation system will attempt to keep the depot load below this limit through the control of EV charging. The optimisation is applied through the following steps:
    - The supply capacity is reduced by a power factor and a buffer to obtain a target maximum load for the site. This adjustment is designed to reduce the chance of sudden changes in load breaching the connection capacity. The power factor and buffer can be set on a per-depot basis
    - The optimisation system regularly monitors the load at the depot (via the building load monitoring) by checking the measured building load and current EV charging demand. If the EV charging demand in combination with measured building load is greater than the target maximum load, then the optimisation system will recalculate available capacity for charging
    - The optimisation system can then determine which setpoints (maximum allowable power) should be sent to each of the individual charge point sockets with an EV currently charging and instructs the charge point controller to apply the setpoints to the appropriate charge points
    - As the capacity available changes this process repeats and the setpoints are adjusted.

- **Profiled Connections** – a variable ASC is specified for the depot by the DNO.
    - The profiled connection is entered into the optimisation system, or CP back office for each depot
    - The maximum load can vary at intervals of 30 minutes and be entered either as a profile that applies to all days of the week or individual days, depending on what is

agreed with the DNO. Start and end dates can be set, allowing for seasonally changing or temporary agreements
    - The profiled connection can be viewed in a depot dashboard, in order to allow compliance/breaches to be identified by the end user
    - As with load management, a configurable buffer is set for each depot in order to prevent breaches of the connection limit caused by sudden changes in load. This is applied to the profiled connection. The profiled connection minus the buffer determines the available capacity for the depot
    - The optimisation system frequently monitors the load at the depot by checking the measured building load and current EV charging demand. If the EV charging demand, in combination with measured building load, is greater than the available capacity under the profiled connection, then the optimisation system will determine which setpoints (maximum allowable power) should be sent to each of the individual CP sockets with an EV currently charging. The optimisation system then applies the setpoints to the appropriate CPs
    - If no optimisation system or building load monitoring system is to be used, the profiled connection can be entered into a back-office system, and the EVs will charge to the prescribed setpoint. However, if the building load 'spikes' to a level not previously seen, there is a risk the profile may be breached.

- **Time of use tariffs** – this optimisation option allows users to configure the amount of throttling (limitation of load) for a depot that should happen within a given time window. This allows the depot manager to restrict charging at times of peak power prices
    - The throttling pattern takes the form of a percentage reduction in load at a specific time. A 100% reduction will reduce load to the minimum allowable level
    - The constraint pattern is entered into back office/optimisation system and applied to the depot
    - For each execution of the optimisation the resultant setpoints returned are sent to each of the active CPs via the back-office system.

- **SoC prioritisation** – this optimisation option prioritises charging to vehicles with a lower SoC relative to the other connected EVs.
    - The optimisation system maintains a catalogue of battery and charging specifications for each vehicle. This data is used to determine the battery capacity and maximum charging speed for each EV
    - Each EV has an RFID tag associated with it and this is used to identify it when it connects and initiates a charge at one of the charge points in the depot
    - Telematics data supplied in real-time provides the current SoC for each vehicle
    - For each execution of the optimisation, the current SoC of each EV, along with its battery attributes, are calculated to determine the setpoints to send to each CP in order to prioritise the lower SoC vehicles. The optimisation/back-office system sends this to the CPs.

<u>**Interface with DNO (profiled connections)**</u>

- The DNO will monitor the load via its ANM system, which would be linked to a network load monitoring device fitted on the DNO side of the meter
- Where a profiled connection has been agreed with the DNO, a process is required to ensure the profiled connection is not breached. In the programme, this was an e-mail alert to the CP control group, based on the DNO's active monitoring of the site's load. This can be configured by the DNO depending on the magnitude and the duration of a breach before an alert is triggered

- If the profile is breached, the CP control group would be notified by an alert and be expected to reduce load within an agreed time limit
- As a failsafe, the EV CP load could be connected to separate circuit breakers from the remaining building load, such that the EV circuit breakers can be tripped by the DNO, if the profiled connection was breached, without impacting other operations. The customer would be expected to re-energise (close) the breaker once the cause of the break of the profile has been rectified
- If the customer re-energised their breaker whilst the load is still in breach of the profile, the above process will be repeated and the customer will be tripped again.

2.3.2 Providing flexibility services

Should a fleet wish to provide flexibility services to the DNO, the following should be considered:

- The project's optimisation system was integrated with the DNO's ANM system, in line with the DNO's security standards and configured to respond to flexibility requests for demand turn-down during specific periods
- Processes and systems should be set up, either by the fleet or through engaging with an aggregator, to forecast EV demand, from telematics and EV charging data, in order to assess when demand for charging is required, when it can be turned down, how much it can be turned down by, for how long, and when charging needs to re-commence in order for the EV to be ready for the next day's business operations. This forecast can then be used as part of the tender and bid process with the DNO
- Turn-down is achieved by restricting EV charging when required and shifting the demand to periods after the contracted flexibility window. The optimisation system was used to compute the necessary setpoints for each active CP throughout the flexibility event.

The following sections highlight the different processes implemented for the flexibility products, which flexibility systems would need to facilitate.

A firm forward option demand response service (Product A):

- A depot was set up as a single FU – i.e., an aggregate load point on the network – based on which the ANM system would issue flexibility requests to the provider
- A process was set up where the bid was made with the DNO as part of an offline process one month in advance of flexibility being required. Once accepted, the bid parameters (start, run-time and flexibility turn down amount) were entered into the system.
- The DNO sent a dispatch signal in near real-time (approximately 15 minutes ahead of need) via an application programming interface (API) message. When dispatches are received for a specific FU, the system checks that there is an active flexibility event, and that the requested turn-down does not exceed what has been offered, before enacting demand turn-down.
- On receiving a dispatch signal of zero kW, reaching the end of the flexibility window or the end of the run time, the system ends the provision of flexibility and the setpoints for each CP are recalculated
- The forecasting of the flexibility bid considered the method by which the DNO will baseline what the load would have been without the turndown event. This is because payment will be calculated based on the DNO's calculation of the baseline from which the turndown that has been offered by the fleet, was delivered.

A day-ahead or within-day auction-based demand response service (Products B and C)

- Each depot is represented by a separate FU and homes were aggregated together into groups which formed a FU.

- Bids were made, per FU, through API messages between the fleet and DNO systems. Bids are made following the receipt of an invitation to tender, on the day before delivery, although the system allows the sending of bids in advance to cover weekends and holidays. The timing of the gate closure for submission of bids is set either day (B) ahead or an hour ahead (C)
- For each FU, a utilisation price (in £/MWh), baseline load (in kW) and flexibility turn-down offer (in kW) are entered for each half-hour period. The flexibility turn-down and price can be set to zero when the FU is not offering flexibility, but the baseline should continue to be sent, because it is used to measure forecast accuracy.
- On submitting the bid, three API messages are sent to the DNO's ANM system containing:
  - The scheduled demand
  - A deviation schedule for each half hour reflecting the flexibility offered, and
  - A utilisation price for each half hour.
- Following the gate closure and analysis of bids, the DNO's ANM system sends an API message in response with a revised schedule. This will be the scheduled demand, reduced by the accepted flexibility for each half-hour.
- The flexibility provider's system validates that the revised schedule complies with the bid and then implements the revised schedule, sending the maximum capacity available for charging (from the revised schedule) and the number of vehicles currently plugged in to the optimisation engine shortly before each half-hour period commences. Setpoints are generated and passed down to the CPs
- Setpoints for each charger are regularly recalculated to take account of changes in the number of vehicles plugged in, ensuring that the turn down is delivered (but not over-delivered because this will not be paid for)
- At the end of the flexibility schedule, the optimisation system either begins implementing the schedule for the next period or, if there is no schedule set, ends the provision of flexibility
- Settlement – a process is required to send the DNO the meter readings each month, following flexibility delivery, to allow the DNO to calculate the payments. A process is also required to confirm payment and resolve any disputes.

2.3.2.1 Requirements for the network operator

In order to implement the flexibility methods trialled in the project, the DNO needs to put in place technology solutions and processes that interact with the customers offering demand response services:

Flexibility services – the following systems and processes will be required to operate flexibility services with EVs:

- A system is required to assess where and when constraints are likely to occur
- A pre-qualification process is needed to register assets able to provide demand response, to ensure they are technically capable and to determine what products the assets can respond to
- A tender process for the flexibility turndown product needs to be formulated to issue to fleets, assess the bid responses and accept
- Once accepted, the agreed bids need to be communicated to the fleet either via an offline process (as in the month ahead trials), where a bid schedule was sent to the fleet, or via an electronic interface (as in the day head or within day trials), via an API, to the fleet. In the Optimise Prime trials this was run as part to the ANM system

- A process to establish the baseline load needs to be agreed, and for this method to be transparent with the fleet – this can either be based on submissions by the fleet operator or an agreed baselining process
- Following the flexibility delivery, the DNO needs to be able to accept the meter readings, from the fleet, calculate the settlement, and pay the fleet
- A settlement dispute process should also be established to resolve settlement queries.

Significant testing needs to take place to ensure both processes work, and in particular that the FUs correspond in the DNO and fleet systems.

2.3.3 Enabling profiled connections

In order to participate in profiled connections there, customers need to ensure several technology solutions and processes are in place:

- Load at the site must be monitored in order to understand the available headroom for charging and calculate what profile can be adhered to. The measurement of background load can then either be used to manage available headroom for charging in close to real time (as was carried out in the project) or historical peaks in load can be used to set charging limits.
- Smart/managed charging needs to be implemented at a site to ensure EV charging does not make the site exceed the profiled connection limit. This could be achieved in two ways:
    - Implementing an optimisation system, as implemented in the project trials, that captures current load data and dynamically varies the setpoints of CPs based on available headroom.
    - Setting load limits that vary over each day for each CP (or groups of CPs) via the CP back-office system, considering the agreed profile and the historic background load. This method may be simpler to implement but requires the functionality to be available in back-office software. A solution of this type may be more suitable for sites where there is limited or more predictable background load
- The customer needs to agree failsafe actions with the DNO. If necessary the CPs will need to be connected to a separate distribution board so that CP load can be shed by the DNO in the event of a breach without impacting other on-site operations
- The customer needs to allow the DNO to install monitoring and control equipment at their site.

2.3.3.1 Requirements for the network operator

The following is required to monitor a fleet's adherence to a profiled connection:

- A network monitoring device that is located on the network side of the point of connection, monitoring the full building load
- The monitoring device will send real-time monitoring from the current sensors, attached to the meter cable tails, to the ANM system
- The ANM system will determine whether or not a profile is being adhered to, or breached
- If the depot load is being breached, the DNO will inform the depot via an alert (e.g., email), to reduce the EV load. The ANM timer will then start
- If the depot remains in breach, and the ANM timer reaches its time limit, ANM will send a trip signal to the remote terminal unit to shed the EV load.
- The DNO and the customer will agree failsafe actions for profiled breaches during the connection agreement stage, whether it is EV load disconnections, financial disincentives or a hybrid approach
- As a failsafe, if there was a loss in communication between the network monitoring device and the DNO, ANM could send a trip signal to the remote terminal unit.

- Actions when there is loss of communications will be decided by the DNO and agreed with the customer during the connection agreement stage.

2.3.4 Guide and operating model for fleet electrification

A draft Operating Model for fleet operators was presented in Deliverable D5. The Operating Model provides fleet operators with an overview of the process for installing EV charging, highlighting the potential benefits of the project methods where appropriate.

This updated guide is now available as a stand-alone document and can be found in Appendix 6 of this report, as well as on the project website at: https://innovation.ukpowernetworks.co.uk/wp-content/uploads/2022/11/Fleet-Electrification-Guide-and-Operating-Model-v1.0.pdf.

3 Implementation of project methods

3.1 How UK Power Networks will be integrating the methods and findings with business-as-usual DNO/DSO processes

3.1.1 Method 1 – Flexibility services to DNOs from commercial EVs on domestic connections

UK Power Networks is committed to a flexibility first approach to meeting requirements for network reinforcement. Flexibility is used in place of network reinforcement wherever it is found to be more cost effective to network customers. This approach requires increasing amounts of flexible capacity at different points of the network in order to provide sufficient capacity. UK Power Networks is continuing to develop its use of flexibility and will take the findings from the project into account when developing future flexibility products. These include:

- Learnings from the use of the UK Power Networks ANM system to dispatch flexibility services for day ahead products and in near real time automatically
- Design of flexibility products and related processes that consider the variety of assets that may be providing flexibility and the differing predictability, allowing more EVs to take part in future bids, and offer larger amounts of demand response
- Consideration of the impact of secondary peaks in the design and dispatch strategy of flexibility products.

3.1.2 Method 2 – Planning tools for depot energy modelling, optimisation with profiled network connections

Profiled connections build on an existing timed connection product offered by UK Power Networks. Based on the learnings generated through the trials of Method 2, UK Power Networks is taking the following actions:

- The Site Planning Tool has been launched by UK Power Networks for use by customers planning their EV transition. While the tool was originally conceived as part of the Profiled Connections product it has proved useful in helping a range of customers consider their infrastructure and power requirements before making a formal connection request. Further details of the Site Planning Tool are given in Section 3.2 below
- Systems have been updated, including the network planning tool and the monitoring capabilities of the ANM systems to allow the offer and monitoring of profiled connections

- Work is ongoing to finalise the ANM failsafe functionality and implement the contractual and process changes necessary to offer profiled connections to customers as a standardised product.

In addition to the method-specific learnings, the data on EV charging usage patterns will help UK Power Networks to adapt their investment plans to ensure they support fleet electrification while continuing to deliver the best value to bill payers. Scottish and Southern Electricity Networks will also be utilising learnings from the project as they shape their EV flexibility and connections offerings.

3.2 Site planning tool

3.2.1 Methodology & Reference Design

The Site Planning Tool was developed as part of Method 2 to help customers understand their EV load pattern in order to apply for a profiled connection. The tool also has a wider application in helping fleets plan their connection and infrastructure requirements even when a profiled connection is not required. In order to help DNOs or other stakeholders understand how the site planning tool works and consider whether it could be of help to their business a methodology and reference design has been produced. This document can be found in Appendix 7.

3.2.2 Using the Site Planning Tool

The site planning tool is free to use for any fleet manager or other interested party looking to understand how their connection requirements could be reduced through the smart charging of EVs. The tool can be accessed on the Optimise Prime website at https://www.ukpowernetworks.co.uk/optimise-prime/site-planning-tool-introduction. The website provides comprehensive help pages providing users with guidance on the data needed to use the tool and how to interpret the results.

An additional tool, the site electrification planner provides a simpler triage tool for customers before they progress to the main tool. The planner informs customers whether they can charge within their existing supply capacity without having to gather and input a large amount of data. This can be especially useful for customers on smaller connections who may not have half-hourly metering.

Following the project, the site planning tool will be hosted and supported by UK Power Networks. DNOs and stakeholders with an interest in using the Site Planning Tool can find further details in Appendix 7, or can contact UK Power Networks at: siteplanningtool@ukpowernetworks.co.uk.

3.3 Recommendation for future application of the methods by other GB DNOs

The Methods developed as part of Optimise Prime are designed to be applicable for any GB DNO. To help assure this Optimise Prime has involved two DNO groups, UK Power Networks and Scottish and Southern Electricity Networks, while collaborating with SP Energy Networks' project known as Charge.

DNOs are encouraged to take note of the recommendations included within this report as they take steps to implement flexibility services from EVs to increase availability of flexibility and to ensure a consistent and coordinated process for businesses wishing to implement EV fleets and offer flexibility services.

As many fleets span multiple network areas it is important that a consistent approach is taken by DNOs when implementing profiled connections and flexibility services. This will help manage the expectations of fleet managers, allowing them to implement common solutions across their estates. It is therefore recommended that the methods recommended here are implemented at a national scale.

3.4 Applicability of the methods and findings for EV stakeholders

3.4.1 Fleet Operators

The Optimise Prime project created a range of findings that should be valuable for fleet managers making the transition to electric. These include:

- The fleet electrification guide: highlighting the key steps and main considerations in fleet electrification
- Behavioural and economic studies: highlighting pain points faced by organisations and how they were addressed
- The site planning tool: useful both for planning charging requirements and making more efficient applications to the DNO for additional capacity when required
- Future flexibility and connections products that can save both money and time in the electrification process.

3.4.2 Policy Makers, local and national government

Optimise Prime has consulted with members of local governments in London regarding the findings of the Optimise Prime trials, with a focus on the outcomes of the mixed trial WS3. This information will help local authorities plan the required infrastructure for future needs, drawing on the project's findings on the location and scale of infrastructure required.

Central Government, including the Office for Zero Emission Vehicles and the Department for Business, Energy and Industrial Strategy have also shown interest in the project's findings. With a plan to end the sale of light ICEVs by 2030 it becomes increasingly important that barriers to electrification are identified and managed. The project's work, covered several fields including technical, economic and behavioural matters, and highlighted issues that need to be addressed as the transition increased in scale.

3.4.3 Insights relevant to Ofgem network access and charging reform

The industry regulator Ofgem has put in place a series of reforms to help the energy industry adapt to the decarbonisation of transportation and heating. As part of this, during the project, Ofgem has reached a conclusion on its networks access and forward looking charging significant code review, with changes due to come into place in April 2023.

The results of the project can help to inform the decisions taken in this ongoing reform, especially regarding how DNOs can use of time-profiled connections to connect sites at lower cost.

4 Transition of the trials, the infrastructure and technology to Business as Usual

4.1 Future use of trial data and learnings

Optimise Prime created a wide range of data and learnings of benefit to both the energy and fleet management industries.

As part of Deliverable D6 the project has shared an extensive dataset from the trials, including charging and journey data from hundreds of commercial electric vehicles. The data will remain accessible on UK Power Networks' open data sharing platform:

https://ukpowernetworks.opendatasoft.com/explore/dataset/optimise-prime/information/.

In addition to the use of the project methods and the Site Planning Tool, UK Power Networks is utilising the trials data in its ongoing business planning processes. Data from use of battery electric vans and private hire vehicles, including charging times and volumes, is being used to improve Distribution Future Energy Scenarios, and to improve forecasting in the Strategic Forecasting System, where data of this granularity was not previously available. The Distribution Future Energy Scenarios and Strategic Forecasting System results help UK Power Networks make informed network reinforcement decisions.

While some of the data generated is specific to the UK Power Networks and Scottish and Southern Electricity Networks regions, the majority of the data collected is applicable for to DNOs nationwide as they consider the future impact of electric vehicles on their networks.

4.2 Optimise Prime infrastructure and technology

The Optimise Prime project partners developed and implemented a range of technology solutions to support the Optimise Prime trials. Parts of the trials' infrastructure was developed to enable analysis of data for the purposes of the trials, while other elements will be available to allow fleets and DNOs to make use of the project methods.

The project's data platform, which existed for the purpose of the trials only, will be decommissioned. The data captured in the project was shared in the form of Deliverable D6.

Hitachi's charging management technologies used in the Optimise Prime depots are available as part of the Lumada ZeroCarbon Cloud suite of products. More information on this can be found at http://zerocarbon.hitachi.com.
The Site Planning Tool, found at https://www.ukpowernetworks.co.uk/optimise-prime/site-planning-tool-introduction, is now hosted by UK Power Networks.

Centrica's EV and energy management solutions used in the project are available from Centrica Business Solutions – for more information visit:

https://www.centricabusinesssolutions.com/energy-solutions/.

UK Power Networks made several changes to its systems and infrastructure in order to enable the project methods. This included:

- Implementing changes to its ANM system, Strata, to offer and manage new flexibility products and profiled connections
- Making changes to connection planning systems to offer profiled connections with a 48-half-hour period granularity

- Integrating monitoring with the ANM system to provide alerts of profiled connection breaches
- Hosting the Site Planning Tool
- Improving accuracy of Distribution Future Energy Scenarios and of the Strategic Forecasting System.

GB DNOs interested in making use of these developments can contact innovation@ukpowernetworks.co.uk for more information.

5 Conclusions and next steps

5.1 Conclusions

This report forms the evidence for the seventh Optimise Prime deliverable. The project successfully delivered on the requirements of Deliverable D7, and this report provides a comprehensive overview of the results of the Optimise Prime trials, together with analysis of the lessons learnt from the project methods.

This report should prove valuable to any fleet considering the transition to EVs, with highlights including the fleet electrification guide, and TCO models, together with behavioural work highlighting the important aspects of electrification from a driver's point of view. For DNOs and regulators, this report provides important learnings about the applicability of flexibility services and profiled connections, that will be useful in defining plans for the use of time-profiled access rights to improve the efficient use of networks. The report also describes the work carried out to quantify the value of the project methods for DNOs.

The project has answered the three key questions

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

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

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

In doing so it has provided a range of evidence-based recommendations to GB DNOs, to help increase the amount of flexibility that can be reliably secured from EV fleets – allowing more EVs to be connected to the distribution network before costly connection upgrades are needed.

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

5.2 Next steps: Open items & future activities

Following conclusion of the trials, the project has now entered its close-down stage. During this part of the project the team will be engaged in:

- Decommissioning and equipment and systems no longer required by the project partners
- Completing the project Close Down Report

6 Table of Figures

7 List of Tables