NIC Project UKPNEN03 Deliverable D3

Learning from Installation, Commissioning and Testing

August 2021

Optimise Prime

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

Table of acronyms & glossary

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

Table 1 – Table of acronyms

Acronym	Full form
3P-DP	Third Party Data Provider
AC	Alternating Current
ADSL	Asymmetric Digital Subscriber Line
ANM	Active Network Management
API	Application Programming Interface
ASC	Authorised Supply Capacity
BAU	Business As Usual
CP	Charge Point
CS	Charge Socket (there may be multiple CS in each CP device)
CSMS	Charge Station Management System
DAI	Data, Analytics & Innovation
DC	Direct Current
DER	Distributed Energy Resource
DDLC	Data Delivery Lifecycle
DNO	Distribution Network Operator
DNP3	Distributed Network Protocol 3 (a communications protocol)
DSO	Distribution System Operator
ESO	Electricity System Operator
ETL	Extract, Transform, Load
EV	Electric Vehicle
EV-CPC	Electric Vehicle Charge Point Controller
FAT	Factory Acceptance Testing
FSP	Full Submission Pro-forma (in reference to the project proposal)
FSP	Flexibility Service Provider (in reference to flexibility products)
FU	Flexible Unit
GB	Great Britain
HCP	Hitachi Content Platform
HV	High Voltage
ICE	Internal Combustion Engine
IT	Information Technology
kW	Kilowatt
kWh	Kilowatt hour
LAN	Local Area Network
LCT	Low Carbon Technology (e.g. solar photovoltaics, battery storage)
LPN	London Power Networks plc
LV	Low Voltage
MAC Address	Media Access Control Address (a unique identifier for a network connected device)
MWh	Megawatt hour
NIC	Network Innovation Competition
OP	Optimise Prime
OTA	Over-the-Air

Acronym	Full form
PHV	Private Hire Vehicle
PS-DP	Partner Systems Data Provider
QA	Quality Assurance
R2H	Return to Home
RAMS	Risk Assessment Methodology Statements
RFID	Radio-Frequency Identification
SDLC	Software Delivery Lifecycle
SGS	Smarter Grid Solutions
SoC	State of Charge
SPN	South Eastern Power Networks plc
SSEN	Scottish & Southern Electricity Networks
SSV	Shared Services
TCO	Total Cost of Ownership
TfL	Transport for London
TOA	Trials Operational Applications
UI	User Interface
UK	United Kingdom
USP	Universal Service Platform
UUID	Universally Unique Identifier
VPN	Virtual Private Network
WS	Workstream

Table 2 – Glossary of terms

Term	Definition
Un-managed charging	Charging of an EV at the rate set by the connection until it reaches full charge or is disconnected.
Smart charging	Charging via a smart charger equipped with two-way communication, enabling charging habits to be adaptive.
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 3 flexibility products: **Product A** – Firm Forward Option; **Product B** – Spot Market; **Product C** – Balancing Market.

Executive summary

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

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

Through cross-industry collaboration and co-creation, the project aims to reduce the impact of EVs on distribution networks and ensure security of electricity supply while saving money for electricity customers, helping the UK meet its clean air and climate change objectives. The trial period for all three project workstreams started on 1 July 2021 and is due to conclude in June 2022.

Optimise Prime's outcomes will include:

- Insight into the impact of the increasing number of commercial EVs being charged at domestic properties, and commercial solutions for managing home based charging
- A site planning tool and 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 third Optimise Prime deliverable, D3, providing a comprehensive overview of the lessons learnt from installing, commissioning and testing the project's systems and infrastructure. Some of the key lessons and challenges, which are discussed in more detail throughout this report, include:

- Aggregation of demand response from distributed EVs can be technically achieved through the system implemented for WS1. In order for a specific customer to ensure that they are able to respond to a flexibility commitment, allowances need to be made regarding the number of EVs available to take account of constraints such as unplanned unavailability of vehicles and urgent need for charging. The project will continue to analyse the reliability of flexibility response as the trials progress (2.4.3)
- Where possible, when implementing a smart charging solution the CPs should be designed/procured together with the control system, to simplify the process of integration, as retrofitting can create significant complexity (3.2.3.1)
- There can be a complex range of actors involved in the provision of depot charging, such as CSMS providers, facility and IT systems maintainers, and it is essential to

clearly define responsibilities during both the installation and operational phases (3.2.3.1)

- The use of RFID tags to identify which vehicle is using which charger within a depot is not always reliable, as tags could be swapped, get lost and replaced or drivers may not authenticate the charging session properly. Tighter vehicle and CP integration (where the vehicle itself identifies to the CP) would make optimisation of charging more reliable, simpler to implement and operate (3.2.3.1)
- Power infrastructure at larger and older sites can be complex and require additional time and resources to implement successfully (3.2.3.4)
- There may be a lack of consistent routines/policies for charging vehicles at the end of shift, and these will need to be put in place to enable smart charging (3.2.3.5)
- Different CPs, settings and firmware can result in varying results. This needs to be understood or standardised in order to effectively optimise (3.3.3.1)
- It’s not always possible to install point of connection monitoring within distribution network infrastructure and installing on customer premises can be complex (3.4.1)
- There may be a requirement to measure both current and voltage to monitor profiled connection adherence and measuring voltage can sometimes be challenging or disruptive (3.4.1)
- When implementing self-service planning tools there is a trade-off between accuracy and ease of use and assumptions need to be made when modelling average weeks based on historic data (3.5.5)
- When charge locations are estimated or forecasted, there is no simple way to accurately map estimated charging demand to network infrastructure at scale, so assumptions need to be made when considering local network impact (4.3)
- Reliance on third party data sources can create risks. Monitoring of data sources is important and periodic changes to data feeds should be expected (5.2.4)

Section 1 introduces this report and provides a brief overview of the systems and solutions that have been developed to support the Optimise Prime trials. **Section 2** details the solutions installed for the WS1 home charging trials while **Section 3** presents details of the solutions implemented for the WS2 depot trials. Both of these sections present an overview of the solutions that were installed, testing that took place and learnings from these activities. **Section 4** presents recent learnings from the WS3 mixed trials activities – while WS3 does not involve the use of physical infrastructure, learnings are presented relating to the activities surrounding the building and testing of the models needed for data analysis. **Section 5** highlights learnings from the IT platform and flexibility work in WS4 that benefits multiple trials, while **Section 6** gives an insight into the project’s quality assurance process and methodology that was used throughout the commissioning process and will continue during the trials. **Section 7** provides a brief update on the progress made in executing the trials. **Section 8** presents the conclusions of this report and the Appendices in **Section 9** provide further detail on testing activities and outcomes.

While the development and testing of the core IT platform and key applications is now complete, the Optimise Prime solutions are being continuously developed using an agile methodology, and as such the project will continue to improve and develop the solutions throughout the duration of the project. Specifically, while the flexibility solution has undergone integration testing to prove system interoperability, full end-to-end testing of some aspects of this solution is ongoing. Any further changes and lessons learned will be captured through future deliverables and in the project close down report.

The project is dedicated to creating solutions that will be applicable to all GB DNOs. This report should prove valuable to any DNO considering how to plan for the future growth of commercial EVs, as well as to vehicle fleet operators planning to implement EV infrastructure and supporting IT systems. Although some aspects of the trial design are specific to Optimise Prime and its partners, the principles and objectives are applicable to all DNOs and to vehicle fleets planning a transition to ultra-low emission vehicles.

Table 3 shows the requirements of Deliverable D3, set out in the Project Direction, and where each item can be found within this report.

Table 3 – Deliverable D3 Requirements

Deliverable D3: Learning from Installing, Commissioning and Testing	
Evidence item	**Relevant section of the report**
Report setting out the key learning points from:	
the installation	Lessons learned from the installation of physical infrastructure at WS1 driver homes the WS2 depots can be found in sections 2 and 3 respectively.
commissioning	Lessons learned from the commissioning of systems can be found in Sections 2, 3, 4 and 5, relating to WS 1, 2, 3 and 4 respectively.
and testing processes/ activities	An overview of the project's approach to testing can be found in Section 6, with results and learnings from the testing activities in each workstream found throughout Sections 2, 3, 4 and 5.

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

1 Background & purpose

This report, the third deliverable of the Network Innovation Competition (NIC) funded Optimise Prime project, describes the approach to and lessons learnt from commissioning and testing the technical systems and infrastructure required to carry out the three Optimise Prime trials. It builds on the work presented in Deliverable D2, which outlined the learnings from the solution build stage.

1.1 Introduction to Optimise Prime

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

Table 4 – Project Partners

Partner	Description	Project Role
HITACHI Inspire the Next	Hitachi is a leading global technology group committed to bringing about social innovation. Three Hitachi companies are project partners. Hitachi Vantara, Hitachi Europe, and Hitachi Capital Vehicle Solutions.	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 Distribution Network Operator (DNO) covering three licenced distribution networks in South East England, the East of England and London. The three networks cover an area of 30,000 square kilometres and over 8.3 million customers.	London Power Networks (LPN) is the project's funding licensee. UK Power Networks provides networks expertise and is developing new connections methodologies and flexibility products.
Scottish & Southern Electricity Networks	The electricity DNO covering the north of the Central Belt of Scotland and Central Southern England.	Supporting experiments within the Central Southern England region, ensuring wider applicability of methods.
Royal Mail	Royal Mail provides postal delivery and courier services throughout the UK. It manages the largest vehicle fleet in the UK with over 48,000 vehicles based at 1,700 delivery offices.	Royal Mail is electrifying depots and operates EVs. Project tools will be tested in the depots and data from the vehicles will be captured.
Uber	Uber is the fastest growing PHV operator in the UK. Over 70,000 partner-drivers use the app in the UK, with the majority in and around London.	Uber is providing journey details from EV PHVs operating in London for the mixed trial.

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.

Data from up to 3,000 EVs driven for commercial purposes will be gathered and analysed. The EVs will primarily be based in London and the South East of England. Optimise Prime will also implement 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.

Optimise Prime aims to be the first of its kind, paving the way to the development of cost-effective strategies to minimise the impact of commercial EVs on the distribution network. Commercial EVs are defined as vehicles used for business purposes, including the transport of passengers and goods. Compared to vehicles used for domestic purposes, commercial EVs will have a much greater impact on the electricity network because of 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 & Southern Electricity Networks) across four licence areas are involved in the project. The consortium includes two of the largest UK commercial fleets and a major PHV operator. This scale will allow the industry to test different approaches to reducing the impact of vehicle electrification on distribution networks, in advance of mass adoption throughout the 2020s. This will also help understand the impact of a wide range of variables, including different network constraints, typical mileage, traffic characteristics, location (urban, sub-urban, rural) and availability of public 'top-up' charging on the feasibility of electrification of commercial vehicle fleets.

By studying this diversity, the learnings generated by the project will be applicable to the whole of GB. Optimise Prime will deliver invaluable insights by using data-driven forecasting tools designed to allow networks to proactively plan upgrades. In addition, this project will create a detailed understanding of the amount of flexibility that commercial EVs can provide to the network through smart charging. Finally, a site planning tool will allow Royal Mail 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 greater network utilisation.

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

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

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

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

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

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

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

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

1.2 Purpose and structure of this report

The purpose of this report is to set out the lessons learned from the installation, commissioning and testing of the infrastructure and systems necessary for the implementation of the Optimise Prime trials.

This report is intended to be used by project stakeholders to guide their activities when installing EV infrastructure and should enable them to transition more smoothly towards EV-based fleets.

- **Section 2** details installation, commissioning and testing activities related to the WS1 home charging trials
- **Section 3** details installation, commissioning and testing activities related to the WS2 depot charging trials
- **Section 4** details testing activities related to the WS3 mixed charging trials
- **Section 5** details installation, commissioning and testing activities relating to the WS4 IoT and flexibility systems serving multiple trials.
- **Section 6** introduces the testing and quality assurance approach that has been taken across the project
- **Section 7** provides an update on the status of the project's trials and the vehicles taking part.
- **Section 8** provides conclusions based on the work done so far and highlights open items that will be worked on in the next stage of the project.
- The appendices in **Section 9** provide further details of the testing activity carried out by the project.

1.3 Infrastructure, technology solution and trials context

The main elements of the infrastructure and technology solution are set out in the Full Submission Pro-forma (FSP) and are designed to support the three trials and two project methods (table 6 below). The trials align with the fleets of Optimise Prime's three project partners, each of which charge, representing home, depot and mixed charging as shown in Table 5.

Table 5 – Optimise Prime trials

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

Two methods will be tested through the trials. They are summarised in Table 6 below.

Table 6 – Optimise Prime methods

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

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

1.3.1 Solution overview

The Optimise Prime technology solution is being developed to enable the trials.

Figure 1 shows the architecture design and key for the project. The core IT solution consists of three main aspects delivered by Hitachi:

- A common data platform that is used to store all project data and host applications, the Universal Service Platform (USP);
- A data, analytics and innovation platform (DAI) that ingests data from a wide range of sources and provides the necessary tools for analysis in the trials; and
- A series of applications (known as the Trials Operational Applications (TOA)) that have been developed in order to size charging requirements, control vehicle charging, test profiled connections and provide flexibility services from Royal Mail depots.

In addition to this, the project partners have delivered a number of other solutions that interact with these IT systems:

- Charge points at British Gas driver homes, connected to a control and aggregation system developed by Centrica in order to provide flexibility services
- A charge point control system for depots, delivered by Nortech, interacting with Hitachi's TOA
- Modifications to a number of systems at UK Power Networks, including connection planning (to enable profiled connections) Active Network Management (ANM) (to manage flexibility and profiled connections) and forecasting.

The goal of the Optimise Prime solution is to provide a digital system that facilitates the execution and subsequent analysis and reporting of the project's trials and experiments. The trials and experiments are orientated around three primary use cases: Home based fleets, Depot based fleets and Mixed public and home charging fleets.

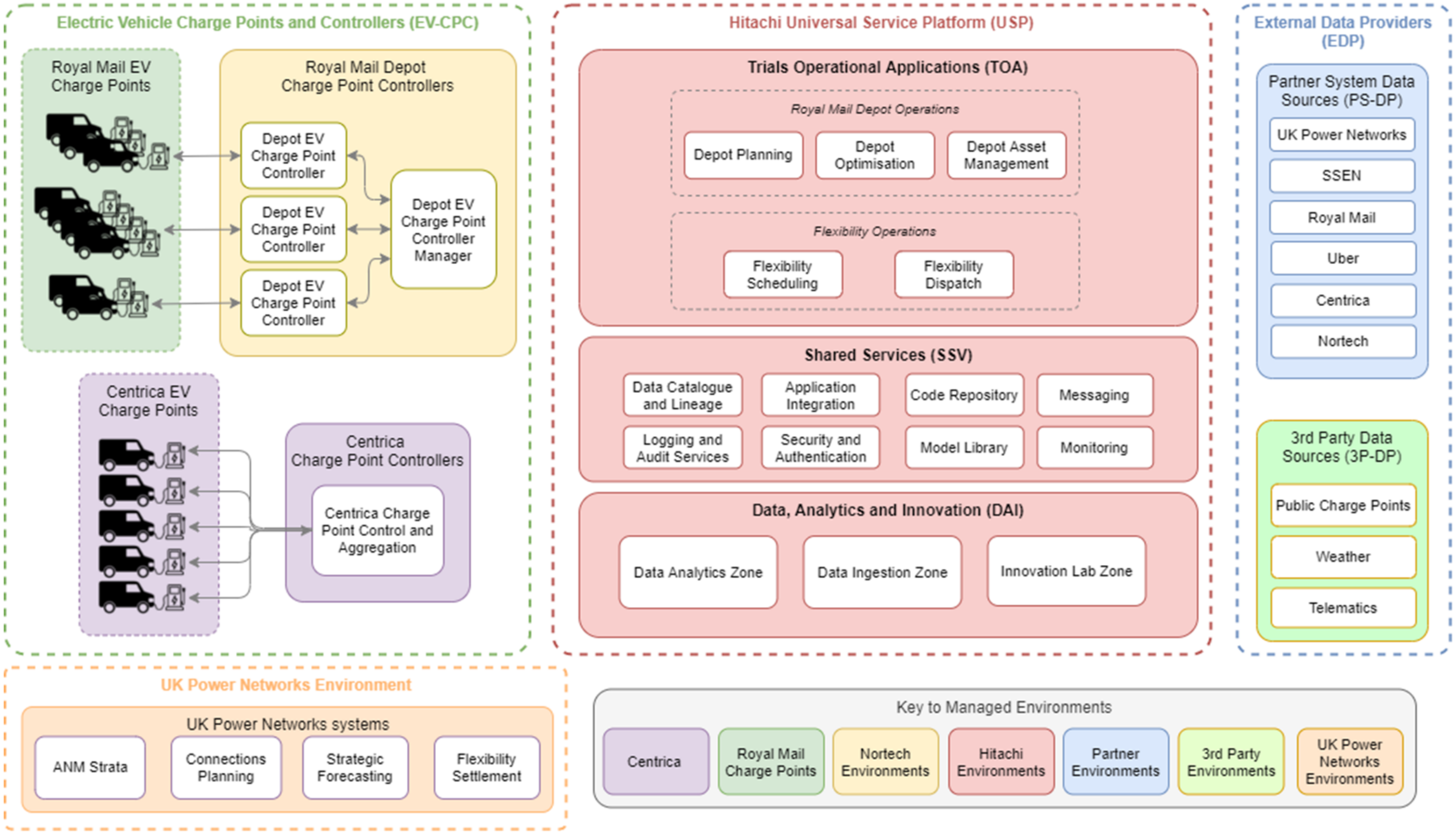
Table 7, provides an overview of how the project's three trials make use of the various sub-systems and solution elements developed as part of Optimise Prime. Details of the testing of elements of the technology solution can be found throughout this report.

Table 7 – Trials and Experiment mapping to Solution Architecture

Trials & Experiments Use Case		Solution Architecture
WS1 Return to Home Fleets	Historical data analysis, modelling and reporting.	External Data sources and DAI sub-system built to load and store telematics and CP (charge point) data for analysis. Provision of analytical tools within the DAI sub-system for performing analysis and modelling.
	Trials of Flexibility Products with UK Power Networks	Implementation of a solution to control CPs at British Gas driver homes to provide flexibility services. Integration of Centrica Business Solutions platform with UK Power Networks' ANM system.

Trials & Experiments Use Case		Solution Architecture
	Trials of Flexibility Products with SSEN	Manual integration of Centrica Business Solutions platform with SSEN's flexibility process.
WS2 Depot Based Fleets	Historical data analysis and modelling	External data sources and DAI sub-system built to load and store telematics and CP data for analysis. Use of a site planning tool to predict load of sites that will be electrified. Provision of analytical tools within the DAI sub-system for performing analysis and modelling.
	Depot planning	A self-service web-based tool allowing fleet managers to model the electricity requirements of different depot and fleet configurations.
	Operational data capture, charging optimisation, analysis and modelling.	TOA sub-system built to provide operational applications that enable the "smart" control of EV charging at Royal Mail depots. Charge Point Controllers installed at Royal Mail depots DAI sub-system used to store analyse the operational data.
	Trials of Flexibility Products with UK Power Networks	TOA sub-system integration with UK Power Networks' active network management (ANM) system.
WS3 Mixed Fleets	Historical data analysis, modelling and reporting.	Data ingestion process built in the DAI sub-system to load and store data provided by Uber. Ingestion process for external data sources from Zap-Map, weather, UK Power Networks, SSEN built to supplement analysis. Provision of analytical tools within the DAI sub-system for performing analysis and modelling.

Figure 1 – Optimise Prime technology architecture



2 WS1 – Learnings from the Home Trials

2.1 Overview of the WS1 solution

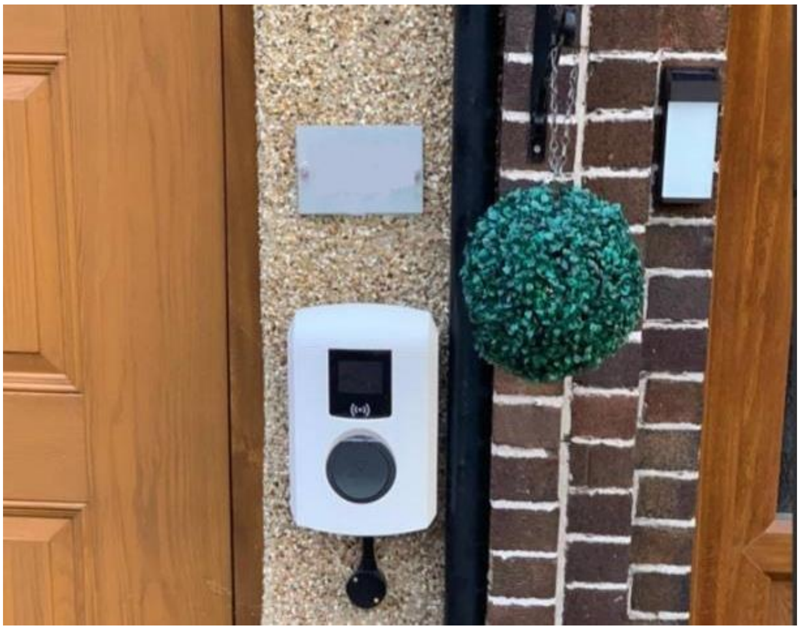
WS1 is the home charging trial, focused on controlling the charging of commercial EVs that are kept at drivers' homes. The trial will collect data from the vehicles and chargers and will test the provision of flexibility services through the control of vehicle charging. In Optimise Prime, the trial will involve Centrica's British Gas maintenance fleet of electric light commercial vehicles.

2.2 Charge point infrastructure installation, commissioning and testing

As described in Deliverable 2, the charging infrastructure utilised in WS1 was installed and maintained by Centrica. Evaluation of a number of CP models was carried out by Centrica in order to select an appropriate model. Key criteria were interoperability, Measuring Instrument Directive (MID) compliant metering, for recording fleet energy usage, including use of RFID, supplier track record and price. The tender was sent to around 15 providers and six were shortlisted.

As a result of this, an Alfen Eve Single CP, as shown in Figure 2, is being installed at each driver's home in advance of them receiving an EV. It will communicate with Centrica's charging management systems using Open Charge Point Protocol (OCPP) version 1.6.

Figure 2 – EV CP installed at a British Gas driver's home by Centrica



The main data sources for WS1 are the EVs and CPs located at drivers' homes. Installation of charging infrastructure at homes has been relatively straight forward, as it was carried out by British Gas engineers at the homes of British Gas employees. Minimal testing was required to ensure the correct functioning of the CPs. British Gas have generally found that drivers have been very accepting of having EV chargers installed, though this is likely influenced by only willing drivers having applied to take an electric van.

The key challenge to the implementation of the charging has been related to the delayed availability of vehicles, as it took longer than initially anticipated for an appropriately sized EV to come to market in sufficient quantities. When EVs did became available, there was also complexity in aligning the delivery and fit-out of vehicles with charger installation and driver schedules over a large fleet.

Not all British Gas drivers have access to off-street parking where a charge-point could be installed. To address this Centrica have made provisions for some drivers to utilise public charging infrastructure. At present very few drivers solely rely on public charging, though this is expected to increase as the rollout progresses. In these cases the CP data will not be available to the project. The British Gas team that is used to install EV CPs at customers' homes use an EV for these jobs. These EVs typically have a daily schedule which requires a top up at public CPs.

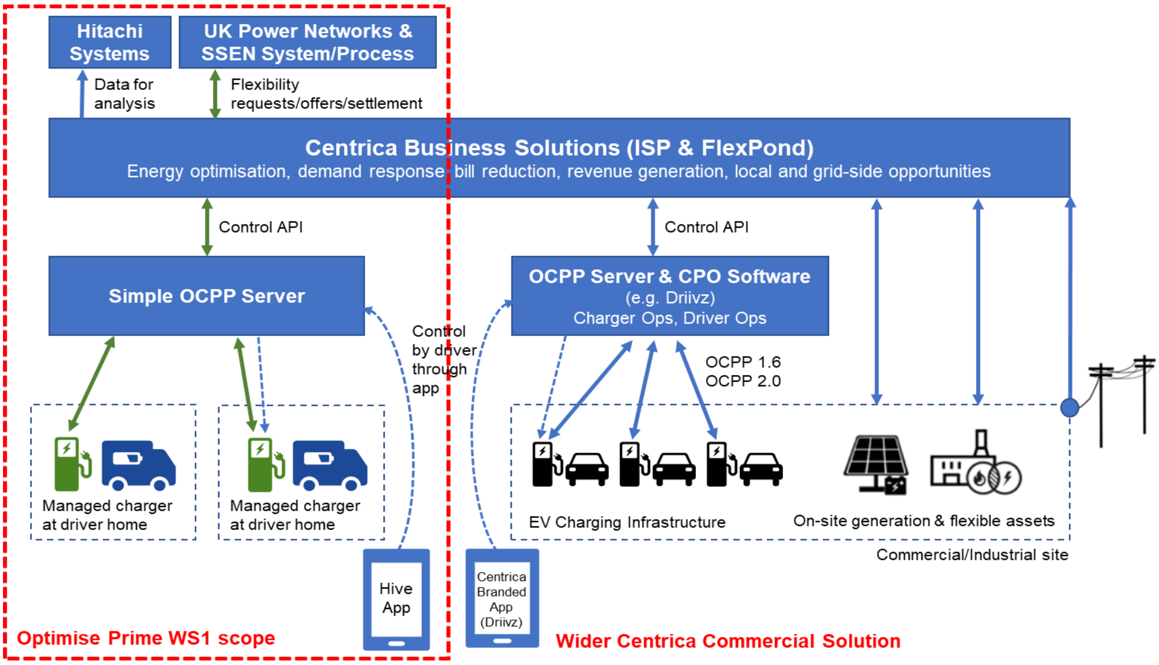
2.3 Systems to monitor and manage charging at driver homes

In order to control the charging of its new EVs, Centrica has developed a new solution based around a driver app which communicates with OCPP 1.6 compliant chargers. Some of the functions that are being built, by Centrica, would have been easier to achieve with OCPP 2.0 (such as the improved device and smart charging functionalities provided by this version), however in line with Centrica's strategy of interoperability, OCPP 1.6 was chosen to provide greater compatibility with a wide range of devices.

The solution has been principally designed around the British Gas home-based fleet use case but can be used by a similar fleet or a home user. Centrica has developed direct integration into their payroll system in order to automatically reimburse drivers for charging their EV at home. The chargers and back-end system communicate with the van's telematics in order to validate that the charge has gone to the van and not another vehicle by comparing charging events across the two systems. Any charge that has gone to another vehicle will not be paid for via the system's automatic reimbursement. This has been done to reduce the cost of expenses reimbursement, which was one of Centrica's main challenges pre-Optimise Prime.

As shown in Figure 3, the app acts as the interface between the driver, the CP and the Centrica solutions for managing charging. It is envisaged that, when the flexibility trials are undertaken, the signal for an event or a dispatch signal will be received by Centrica's Integrated Solutions Platform and FlexPond. A signal will then be sent to the CP via the Control API (Application Programming Interface) in order to delay charging.

Figure 3 – WS1 home trial high level solution architecture



2.4 *Flexibility systems*

The core purpose of the WS1 trial systems is to understand how the flexibility of fleet EVs distributed at drivers' homes can be leveraged to provide flexibility services to DNOs and DSOs alongside their potential participation in other flexibility services such as the ESO-level market and smart charging to create cost savings.

In order to achieve this many factors need to be considered; however the two essential components of the solution are optimisation logic and flexibility management.

2.4.1 Optimisation solutions

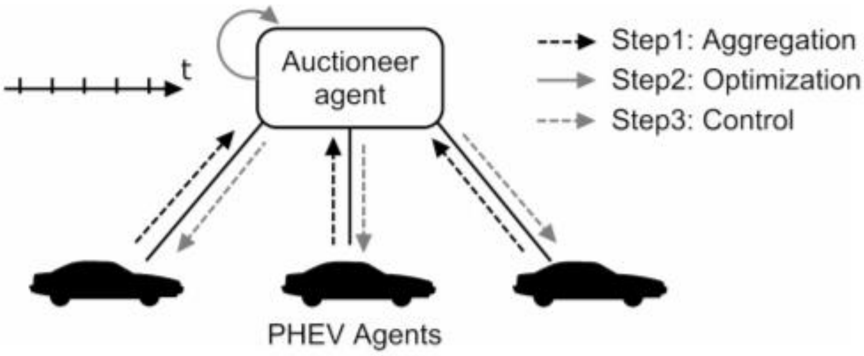
The inclusion of EVs in flexibility programs, especially those related to providing DSO services such as congestion management, effectively results in a sequential decision-making problem under uncertainty, as bids for flexibility have to be agreed in advance, yet there is only limited control available over the load. The decision-making problem is further complicated due to the presence of coupling constraints, as assets need to be allotted to flexible units that may be bound by geography, hence finding sufficiently scalable optimisation solutions is key.

One interesting optimisation approach that is a good trade-off between practicality and optimality is that of "aggregate-and-dispatch" as presented in the papers referenced below[2,3] and in Figure 4. In this approach the charging constraints (such as times when load is expected, and opportunity cost of providing flexibility) from each of the vehicles/CPs is

[2] S. Vandael, B. Claessens, M. Hommelberg, T. Holvoet and G. Deconinck, "A Scalable Three-Step Approach for Demand Side Management of Plug-in Hybrid Vehicles," in IEEE Transactions on Smart Grid, vol. 4, no. 2, pp. 720-728, June 2013, doi: 10.1109/TSG.2012.2213847.
[3] K. De Craemer, S. Vandael, B. Claessens and G. Deconinck, "An Event-Driven Dual Coordination Mechanism for Demand Side Management of PHEVs," in IEEE Transactions on Smart Grid, vol. 5, no. 2, pp. 751-760, March 2014, doi: 10.1109/TSG.2013.2272197.

collected, allowing an optimal aggregated flexibility model to be created for each Flexible Unit (FU). Based on this, bids for flexibility services can be made and when bids are accepted by the system operator control signals are dispatched to the CPs.

Figure 4 –Diagrammatic representation of aggregate and dispatch[3]



2.4.2 Potential for flexibility

As encapsulated by the name, flexibility services require flexibility in the assets being controlled. The graphs in this section present a statistical summary of the flexibility observed with respect to the British Gas fleet, based upon the results of about 8,000 transactions from early EV adopters.

Figure 5 depicts distributions of arrival and departure times per weekday whilst Figure 6 depicts a distribution of the energy charged during a charging session. Bringing this information together suggests that a significant amount of flexibility is available in the order of 10 hours per session. This is a promising result in terms of the flexibility services that can be provided in the context of this project.

Figure 5 – Flexibility statistics of the British Gas fleet, illustrated are the arrival and departure statistics and when the EVs would be charged, clearly indicating a significant amount of flexibility.

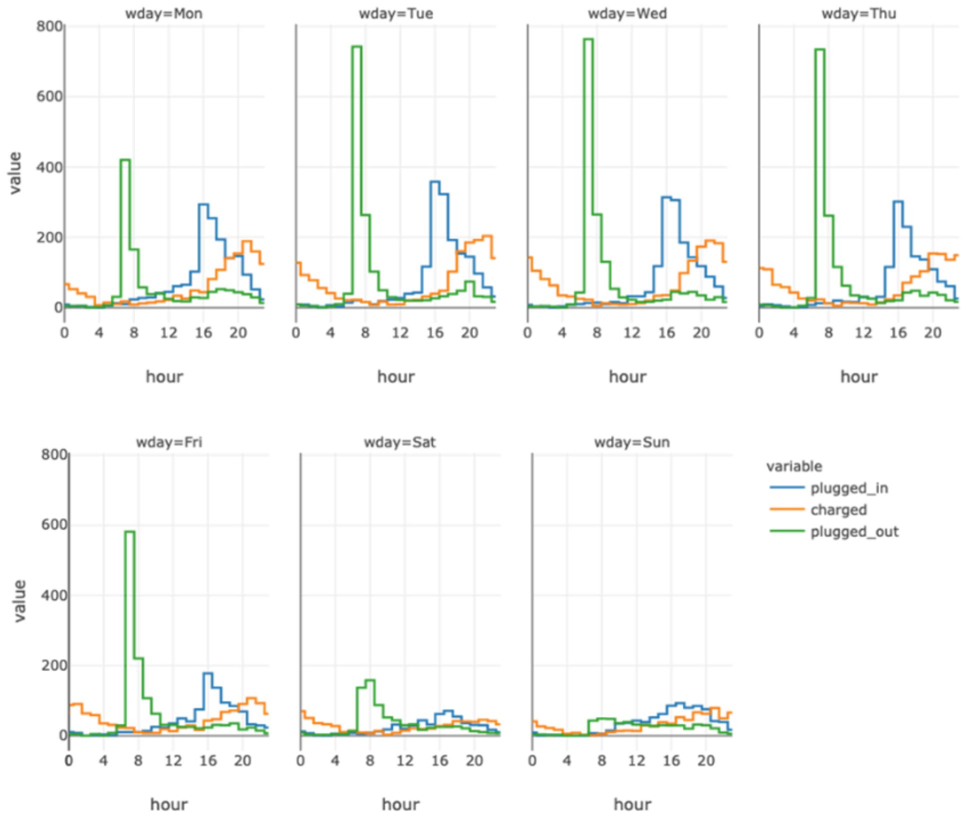
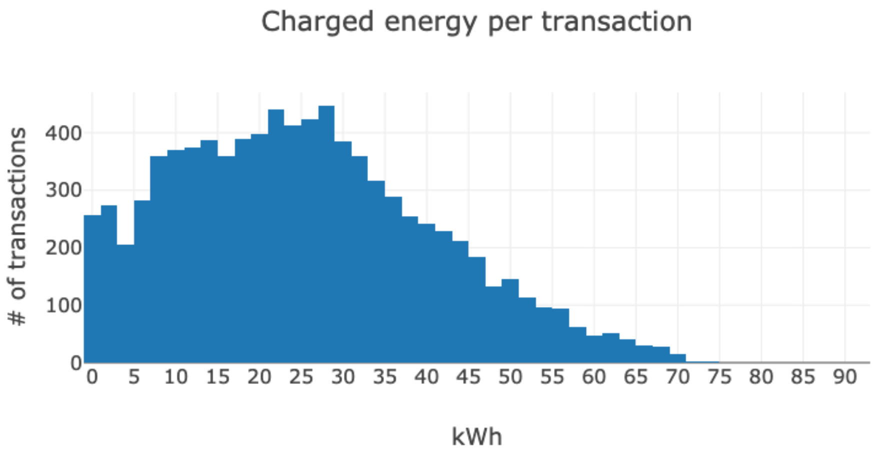


Figure 6 – Distribution of the kWh charged per transaction



2.4.3 DNO flexibility system integration

Integration testing has been carried out between Centrica's flexibility system and UK Power Networks' ANM Strata, developed by Smart Grid Solutions.

The testing involved the technical processes that are required for participation in the Product B (day ahead) and Product C (intraday) flexibility trials – from bid to dispatch. This required testing of the connectivity between the systems, authentication and each of the API messages in the product specification. Development is continuing in order to finalise some aspects of the systems (to run an optimisation cycle within the ANM system that triggers the dispatch, and to control large groups of chargers). Testing of these functions will take place in Autumn 2021 as part of the first flexibility experiments for products B and C.

In advance of the availability of the full end-to-end solution, a test was carried out to verify the ability of the Centrica flexibility solution to control charging of EVs on receipt of a simulated request for flexibility from a DNO. To do this, 20 managed CPs were chosen as a sample and were requested to pause charging from 5.00pm to 7.00pm on a weekday.

Figure 7 – Home CP control test – baseline (left) and results (right)

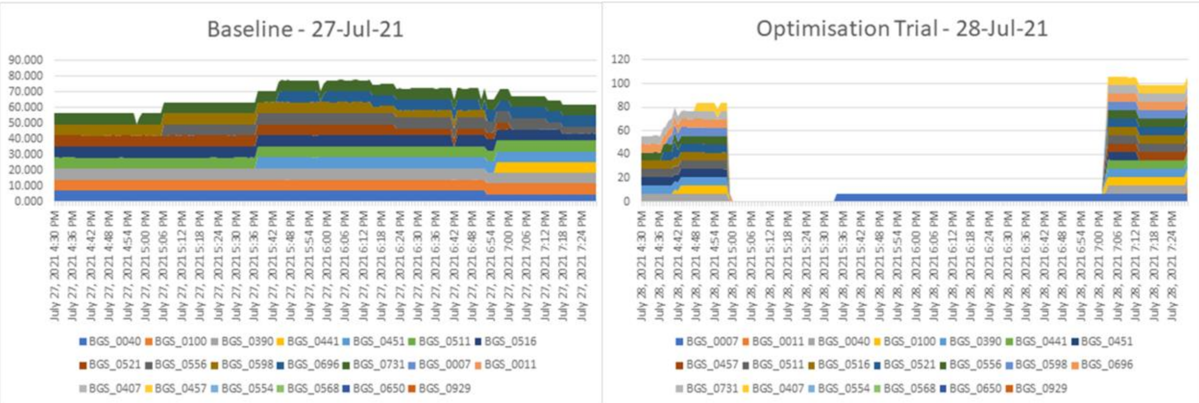


Figure 7 shows the result of the test in comparison to a baseline created on the previous day. The system was successful in pausing the charging of the vehicles, resulting in an 80kWh drop in demand from the connected vehicles, with charging resuming at 7pm. The peak in consumption between 5.30pm and 7.00pm seen in the baseline was avoided due to the implementation of the demand response. During the period of the trial, 15 vehicles were connected to the CPs. During the course of the test, one driver required urgent charging during the period and manually activated charging using the override functionality, as shown by the blue line.

Aggregation of demand response from distributed EVs can be technically achieved through the system implemented for WS1. In order for a specific customer to ensure that they are able to respond to a flexibility commitment, allowances need to be made regarding the number of EVs available to take account of constraints such as unplanned unavailability of vehicles or urgent need for charging.

Initial testing based on a small sub-set of data has shown that it is technically possible to control the distributed CPs resulting in demand response. Around three quarters of the CPs in the trial were able to pause their load for the required duration, during the trials the project will monitor how accurately the response rate can be predicted in order the reliably provide flexibility services.

2.5 Data exchange for analysis

While Centrica will operate the day-to-day charging operations, and provision of flexibility from the British Gas fleet throughout the trials, it also provides a range of data to Hitachi, enabling analysis of the potential future impact of at-home charging on the electricity grid. These data sets are delivered as regular batched and include:

- **Telematics –** Ingestion of historical telematics data for both ICE (Internal Combustion Engine) and EV fleets, to allow data analytics to be conducted to support the relevant

Experiments. This will provide details of the locations and distances travelled by vehicles, when they charge and the state of charge (SoC) of vehicle batteries. This data is provided from Centrica's existing telematics systems.
- **Charge Point –** Ingestion of data from the CP system, including plug in and plug out times, charge duration and energy consumption metering.

The process of implementing this data exchange and exploring the data has generated a number of challenges and learnings which may be of use to other fleets or DNOs:

To measure the transition of ICE vehicles to EV efficiently it would be useful to use a single consistent telematics system

In order to predict power demand from a future EV fleet, and to compare behaviour of EVs within the home charged fleet against ICE vehicles the project uses telematics datasets from British Gas EVs and ICE vehicles. The systems used to produce this data are different, and making the datasets comparable requires a significant amount of data manipulation. In future, fleets should consider whether it is possible to use a unified, consistent system. This will make it easier to identify the benefits that have been realised from the EV transition and will help to manage the interim period when the fleet contains EVs and ICE vehicles.

When implementing and measuring smart/controlled charging, consideration needs to be given as to what data needs to be captured and reported

It was originally intended to summarise data from the CP system to make exchange easier. A set of data was chosen to report each plug-in/plug-out session and the charging that took place within it. However, without detailed minute by minute information on the power being drawn it has proved not possible to see the demand curve of the charging session, or where within the plug-in session the charging took place (i.e. when 'Smart Charging' takes place). Hitachi is working with Centrica to define a data set that provides the required data, while being mindful of the large quantity of data this may result in.

Vehicles may transfer between drivers and this needs to be taken into account

Analysis of the initial months of data has shown that vehicles do not always stay with the same driver and this needs to be taken into account when analysing the journey and home location data. To mitigate any issues within the trials the home location for each vehicle is recalculated and updated each month. When implementing a flexibility system, timely and accurate tracking of asset moves will be important as this may impact availability and location of flexibility.

There is a need to monitor data continually to identify data quality issues

While the project has found the quality of the data to be good, some anomalies have become apparent. For example, when assessing EV location and availability for smart charging, Hitachi has had to exclude locations which appear to be maintenance depots and where vans are stored and prepared for service before allocation to drivers. Relevant sites were identified and removed from the analysis so as not to distort conclusions on where demand on the grid might be present. Ongoing analysis is required to take into account any changes in fleet processes.

3 WS2 – Learnings from the Depot Trials

3.1 *Overview of the WS2 solution*

WS2 is the depot charging trial, focused on controlling sites where a number of vehicles will charge simultaneously. In Optimise Prime, EVs at nine Royal Mail depots in and around London will be smart-charged. Trials will test the ability of depots to comply with profiled connections and provide flexibility services at the request of the DNO.

The solution implemented at the depots consists of a number of physical and IT systems which monitor vehicle and charging status and enact changes in vehicle charging setpoints as part of smart charging.

Figure 8 – High level view of WS2 depot solution

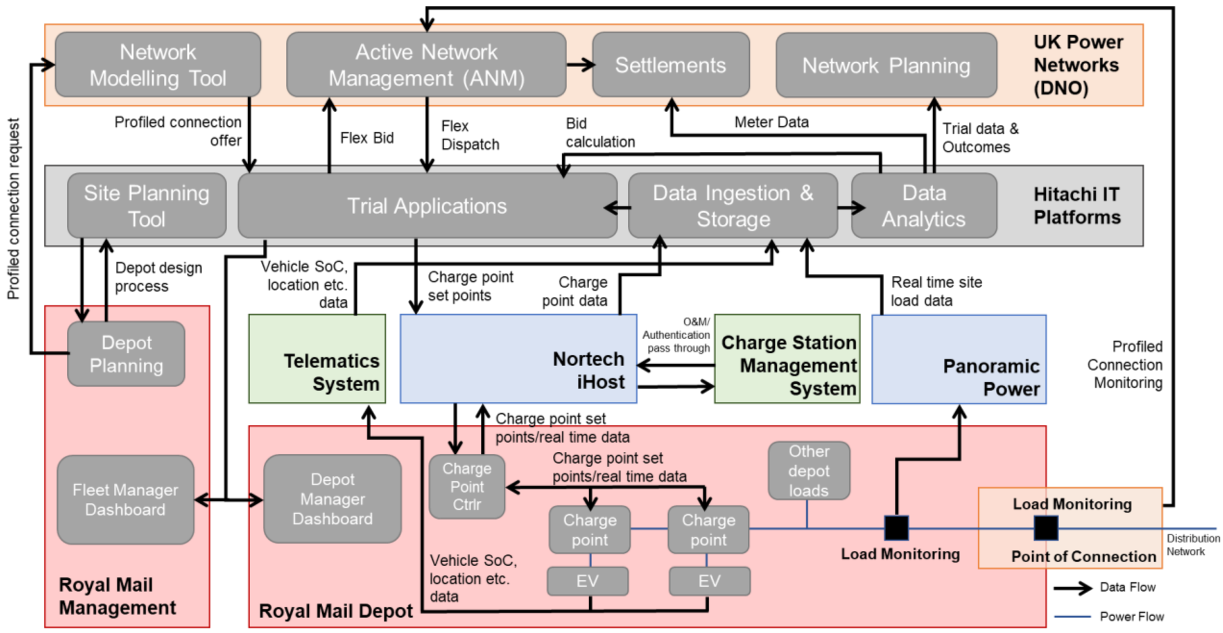


Figure 8 gives an overview of the interactions between different systems and processes within the Optimise Prime solution. The diagram is simplified to show a single depot and two EVs – in reality nine depots are being controlled through the Optimise Prime solution and the largest depot has almost 100 vehicles.

The following pages describe the WS2 solution in more detail, focussing on the challenges faced in implementing the depot systems and lessons learnt that may be useful for fleets implementing smart charging in the future. This section is broken down into four main sections, covering the infrastructure at depots (3.2), the optimisation platform, changes to DNO systems and processes (3.4) and the Site Planning Tool (3.5).

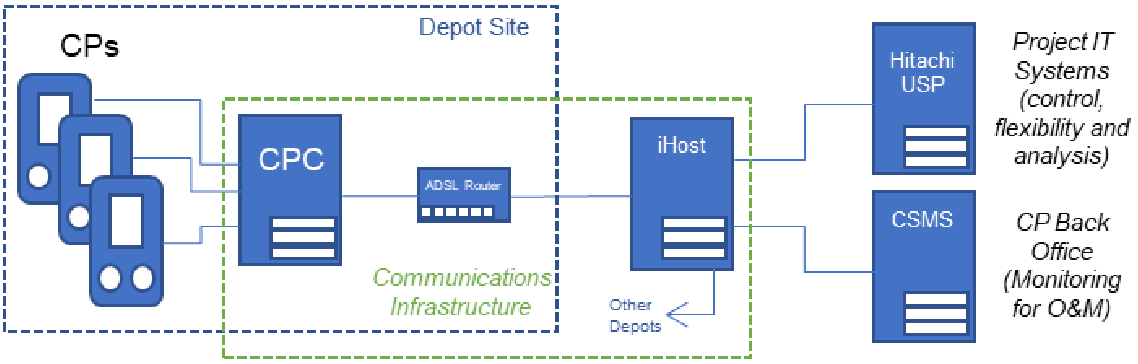
3.2 *Charging and communications infrastructure*

3.2.1 Solution overview

The infrastructure to support the management of smart charging in WS2 was described in more detail in Deliverable D2. It includes CPs and a communications solution, as shown in

Figure 9 , featuring an on-site Charge Point Controller (CPC) and a communication platform connected to all depots (iHost). Together this is referred to as the EV-CPC sub-system. The EV-CPC subsystem has the functionality to intercept messages flowing between each CP and the Charging Station Management System (CSMS, commonly known as a 'back office' system) and divert them to an optimisation system, hosted on the project's platform.

Figure 9 – WS2 charging infrastructure



The Hitachi USP system sends new CP setpoint commands to the Communications Infrastructure to adjust the charging rate of the CPs, based on the outcome of the optimisation.

This basic methodology was identified as a requirement for the project's method because when the project's architecture was designed it was not possible to accomplish this via the CSMS (because the project does not own or control the CSMS).

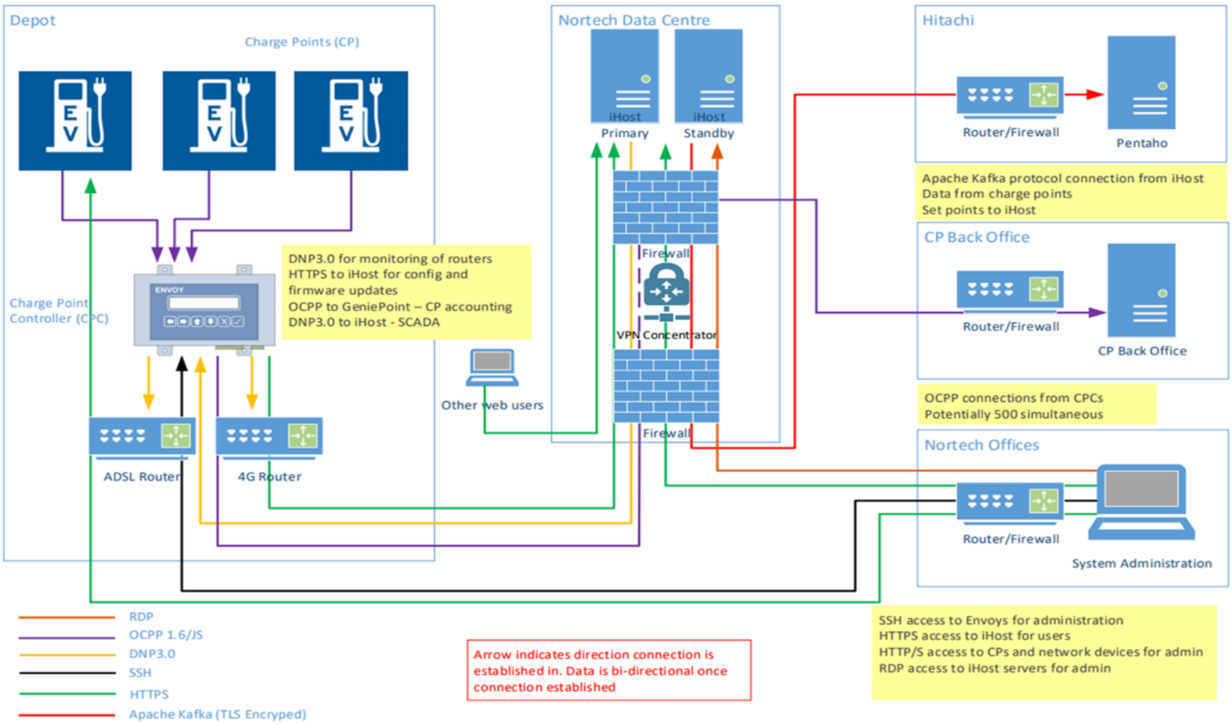
The CPs were installed by Royal Mail. The CP estate consists of a mixture of devices – older Swarco E-Volt dual socket CPs, installed before Optimise Prime, and newer Alfen Eve Pro single and dual socket devices. Some depots have a single type of CP whilst others have both types installed.

The Swarco CPs are connected to Swarco's e.connect CSMS while the Alfen CPs are connected to Engie's GeniePoint CSMS. The CSMS systems are used to authenticate charging sessions (via the RFID fobs) and by Royal Mail's suppliers to provide monitoring and maintenance services. The infrastructure is commissioned and delivered into the project as a functioning EV charging system. At this point there is no integration with the Optimise Prime infrastructure.

Nortech was contracted by Optimise Prime to install and manage the EV-CPC sub-system of the Optimise Prime Solution. Figure 10 presents the architecture of the solution. The sub-system comprises the deployment of "Envoy" units (referred to in this document as CPCs), at each Royal Mail depot, to connect to each CP over ethernet and communicate back to Nortech's backend system, iHost, over an ADSL connection. Communication fallback between the Envoy units and iHost is provided over a cellular network. To provide resilience there are two Envoy units installed at each depot, with the load evenly split across the devices. The smart charging communications infrastructure was installed by Royal Mail's contractors in accordance with Royal Mail specifications and to Nortech's design.

Integration between iHost and Hitachi's platform has been implemented behind a secure site-to-site VPN by exposing a Kafka-Proxy instance. The Kafka-Proxy routes messages to the Kafka Broker within the Hitachi's system. iHost provides status and measurement data for each CP socket as structured messages within a dedicated topic.

Figure 10 – Nortech EV-CPC System Architecture



3.2.1.1 Implementation of 'Over-the-Air' (OTA) depot control

As the solution developed, it became clear that it would be possible to implement a variation of the solution without the on-site physical CPC device, or need for cabling by integrating the iHost system, directly with the CSMS, and sending setpoint commands/receiving data via the cellular connection between the CSMS between each CP – i.e. 'over the air'.

This solution could reduce the cost per site of implementing the project's method by utilising existing systems. It was identified that there were however potential negatives to this solution, such as the reliability and cost of cellular data, and the reliance on the CSMS supplier to operate a core system in the solution (which was the rationale behind installing a physical CPC).

It was decided that implementing an OTA solution would bring benefits to the project because it would allow the addition of two further Royal Mail depots (where EVs were already operating) at Camden and Victoria, in addition to six sockets at Whitechapel depot where it had not been possible to install ethernet cabling.

Nortech worked with CSMS provider Swarco to implement this solution. The project will compare and evaluate the benefits of these two methods.

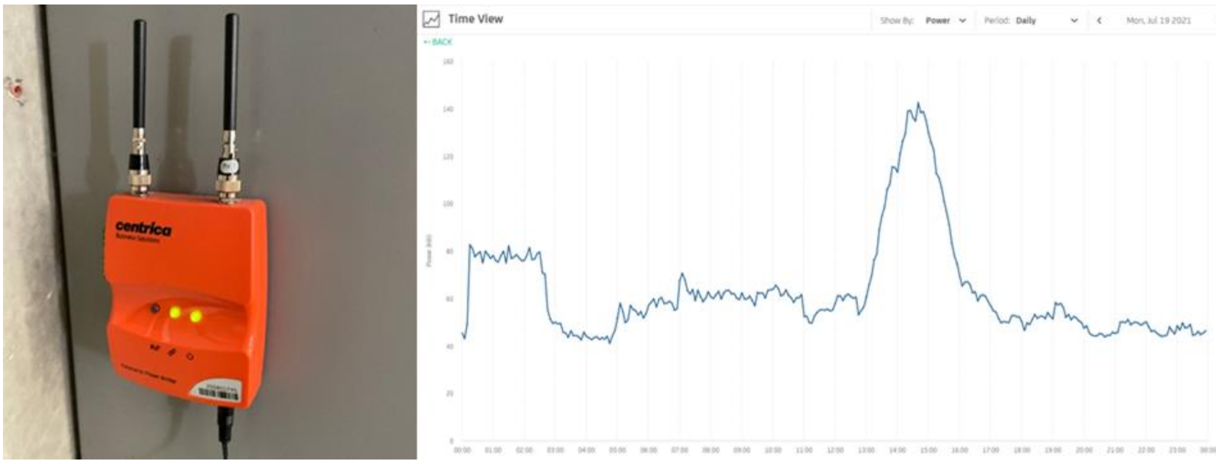
In testing, the solution was also found to solve where the configuration of the CPCs had only allowed the control of one socket at a time on twin Swarco CPs. OTA reliably allows control of both charging sockets and as a result the project is considering rolling out the OTA solution to all Swarco CPs.

3.2.1.2 Implementation of site load monitoring

The Optimise Prime optimisation algorithms depend on site load data to function. 'Headroom' (which is the difference between site load and site capacity) available for EV charging is calculated by deducting other (non-EV) loads from the available capacity of the site.

To provide this data, the Centrica Business Services' Panoramic Power solution was chosen. This solution uses non-invasive wireless clamps to measure the current in each power cable supplying power to the site. This is then relayed to a server via a communications device with a cellular connection (Figure 11). This data can be viewed via a web portal (PowerRadar) and is captured by the Hitachi platform via Panoramic Power's SFTP service. The solution chosen measures current but not voltage – to check the impact of this on profiled connection compliance and flexibility delivery to the DNO, UK Power Networks is implementing more comprehensive monitoring at their point of connection (see Section 3.4.1 for further details).

Figure 11 – Panoramic Power Bridge at a Royal Mail delivery office (left) and example of PowerRadar visualisation (right) showing demand peak from Un-managed Charging at a depot



The device and current transformer (CT) clamps are intended to be installed by the end user and the cost of the solution includes both the equipment and a year's subscription to the service. Given the unknowns around the site power arrangements it was decided to commission Centrica to undertake site surveys and installation.

3.2.2 Approach to commissioning and testing of the charging and communications infrastructure

Systems integration of the EV-CPC subsystem and its components followed a three-stage testing process:

1. Lab testing of each CP configuration at Nortech premises
2. Verification at the project's Factory Acceptance Test (FAT) site
3. Verification at a pilot site followed by each Royal Mail production site

On the FAT site and at the RMG depots integration proceeded in three commissioning phases:

1. **Integration of the Nortech smart charging infrastructure with the on-site Local Area Network (LAN).** Nortech verified that all equipment had been installed correctly and was operational. Physical connectivity between the Nortech equipment and each

CP was verified, but the CPs were not integrated into the smart charging system. Snagging is managed by Royal Mail's contractors.

2. **Integration of the CP units with the Nortech CPC.** At this point all CP to back-office communication was switched from the CP internal cellular modem to the Nortech infrastructure. The system was tested to ensure that from the back-office perspective all functionality operates as before. Setpoint (charging command) functionality was verified from Nortech management systems.
3. **Integration of Nortech's management application (iHost) with Hitachi's optimisation platform.** Functionality was verified end-to-end, i.e. that the Hitachi system could control the charging setpoint of each CP.

This staged and phased approach permitted any operational risk to Royal Mail to be managed and allowed for a period of stability testing following each stage or phase. The primary consideration was always the management of operational risk.

Basic on-site testing of the load monitoring system was completed by the vendor, Centrica Business Solutions as part of the installation process. Connectivity was then tested by the project team by ensuring that measurements from all sensors were visible in the Power Radar web-based monitoring platform.

3.2.2.1 The FAT Site

A factory acceptance testing (FAT) site was set up for the project at Hitachi Capital Vehicle Solutions' Trowbridge site. This facility provided representative parts of the system including each CP variant installed at the Royal Mail sites and associated Nortech CPCs. Nortech was responsible for the installation, commissioning and support of all equipment.

The objective of the FAT site was to ensure that the installation was as close as possible a replica of the Royal Mail installation, though there were some deviations dictated by local constraints (e.g. no Centrica load monitoring was installed). This site is used for pre-release integration testing of system updates, such as changes to CP firmware, and to test the impact of smart charging interventions before they are rolled out to Royal Mail sites. The scope does not include representative EVs, drivers nor Royal Mail operational processes. The CPs at the site are connected to the back office CSMS systems of the project partners.

3.2.2.2 Pilot Site

In collaboration with Royal Mail, a depot was chosen to act as pilot site, where the system can be trialled in a live environment before being rolled out to all production sites. The pilot site, Premier Park in West London, was chosen to provide a fully representative production system with Royal Mail EVs, CPs, CPCs and real end-users (EV drivers, operational and support staff). Hitachi staff attend the pilot site whenever testing is underway in order to observe and rectify any issues that may occur. Piloting solutions in this way was found to be essential, as the limitations of the FAT site meant that issues relating to the specific vehicles used by Royal Mail, or the scale of the operation at depots could not be tested in FAT.

3.2.2.3 Production Sites

There are nine production sites taking part in the project. These encompass Royal Mail depots and their associated EVs, CPs, CPCs and end users. Once the systems were proved at the pilot site, they were implemented the production sites. To allow any issues to be identified and dealt with, production sites went live one by one and were monitored closely.

3.2.3 Learnings from installation and commissioning of the charging and communications infrastructure

Implementation of the depot systems and infrastructure was a major task for the project and resulted in a number of challenges and learnings that are likely to be of use to stakeholders implementing smart charging solutions, especially where this is being done in operational depots and as an overlay to existing charging systems.

This section highlights key learning points and is structured based on the different element of the solution build.

3.2.3.1 Installation of Charge Points

Where possible, the CPs should be designed/procured together with the control system, to simplify the process of integration

The CP estate at Royal Mail comprises pre-existing and new units. The Optimise Prime programme had no influence over the procurement of the CP infrastructure because these were subject to a separate commercial agreement between Royal Mail and their charging supplier. The programme therefore needed to determine the functional capabilities of the CP units to design a solution that worked with these chargers. Furthermore, the new and existing CP units were all installed with cellular connections to the CSMS via a cellular transceiver in each CP. Had the CP fleet been installed using a common LAN it would have made smart charging installation considerably simpler because the reliance on the SIM card GSM communications would have been removed.

Where there are multiple MPANs at site, the CPs should be recorded against which MPAN they are connected to at the time of installation

The CPs that are installed at sites with multiple MPANs (meters) should be documented such that it is clear what capacity has been installed at each MPAN. This will allow the profiled connections to be more accurately designed because the power requirement against the available capacity will be known. Because of the complexity of the electrical set up at some Royal Mail depots it was not possible, post CP installation, to be completely accurate in knowing the installation configuration.

3.2.3.2 Installation of communications infrastructure

Given the CPs were not installed with physical communications infrastructure, it was necessary to install a LAN to support CP communications and complete the manual task of re-configuring each CP from SIM card to use the LAN over the internal cellular transceiver. The preferred installation route was to place a turnkey contract for the installation, commissioning, operation and maintenance of the on-site communications infrastructure. The subcontractor would be responsible for liaison with the CP operator to arrange for the CP units to be migrated from cellular connections to the LAN, as well as providing a link between the CSMS and the smart charging system. The scope also included the installation of the on-site LAN cabling infrastructure.

Depot operators may have existing policies and procedures and support arrangements that need to be considered when planning and designing any solution

During planning for the installation, the necessity of ensuring that the installed cabling met the specification of the site owner (Royal Mail) became clear. The decision was taken to use Royal Mail's own existing contractors to install the cabling for data and power (to Nortech's requirements). This ensured that existing support arrangements for data cabling infrastructure could be used to provide maintenance of the smart charging LAN.

As a result of this, Hitachi, as programme manager, placed orders with RMG for the cabling and power at each site, and a separate order with Nortech for the installation and commissioning of their iHost network equipment at each site. Although no longer a turnkey contract, Nortech managed on-site works, with assistance from Hitachi. This exercise proved time-consuming and introduced commercial complexity and cost, as well as delaying the installation, whilst commercial arrangements were agreed. The approach of dividing the work according to area of responsibility and assigning one party as the lead responsible for coordinating the sub-activities remains valid, but for future activities any coordinating role and constraints should be clearly determined prior to contract placement. Furthermore, the impact on support arrangements need to be fully assessed when an additional party is included (i.e. Nortech).

Site surveys are critical, and provision should be made for future communications infrastructure when installing CPs

The importance of detailed site surveys, particularly on older sites with a history of change, should not be underestimated. Cable routing at some older sites proved to be particularly problematic. Site surveys were conducted at each site and revealed the importance of physical constraints on cabling. For example, in the case of one site (Whitechapel) the three existing Swarco CP units are installed on plinths rather than fixed to a wall. The consequence was that it was not feasible to physically connect them to the LAN due to constraints on cable routes and access and therefore they could not be controlled. The OTA solution, described in Section 3.2.1.1, now allows these CPs to be controlled remotely. Whilst cellular connection clearly offers a simpler installation for CP operators, it does so at increased operational cost and reduced future flexibility for networking of CS units. It is prudent to ensure that CS units are always installed with the possibility of future wired connectivity in mind, particularly where GSM coverage is poor.

3.2.3.3 Charge Point control system

The following learning points relate to the implementation of the CP control system at each site, and integrating the systems required to enable CP control.

Early involvement of operational staff and third parties is key to ensuring that commissioning proceeds with minimal disruption

The delivery of the smart charging solution for Optimise Prime has unavoidable dependencies on third parties with whom there is not a contractual relationship (because this relationship is held by Royal Mail). Operational depot managers may also be reluctant to make changes to routines if they do not fully understand what is being implemented.

This necessitated a comprehensive programme of communication in order to explain programme objectives in such a way that all stakeholders can perceive a benefit for themselves. Optimise Prime is trialling new and innovative technologies, and it is clear that some form of smart charging will be essential to support future EV fleets. Therefore, early experience with and exposure to the technology is a clear benefit to all involved with fleet electrification.

Changing requirements as the solution develops

While the project set out a clear design for the depot charging solution at the outset, due to the innovative nature of the solution some requirements of the solution only became apparent as the design and testing progressed. The CPC solution, from Nortech, (incorporating hardware on each site and a back-end system) was procured at an early stage in the project, based on expected requirements, but the requirements on the provider (both in terms of technical functionality and responsibilities) have had to be revised over time (e.g. the decision to implement the OTA solution; the frequency of 'setpoint' commands being sent to the CP). Where this is likely to be the case it is important to ensure that there is sufficient flexibility in the contract with the suppliers, sufficient budget available and the supplier is fully aware of the potential for significant change.

Role and importance of the CPC supplier

Further to the above point, the CPC supplier's role developed during the project. While the EV-CPC subsystem was originally considered as a passive solution, directing setpoint commands from the Hitachi platform to the CPs, it developed to have a key role in interpreting the measures received from the CPs and consolidating them into a single data feed to the main platform. In the other direction taking many setpoint commands and ensuring that they are enacted by the CPs. Careful attention should be taken regarding the design of this type of system, in tandem with the main optimisation system, to ensure that the end-to-end process works as designed and all necessary measures are captured.

It also transpired that the CPC system had to take a more complex role in the management of the CPs, such as interfacing with the CSMS provider's systems and managing firmware updates to the CPs. Additional functionalities were also added to the scope, such as over the air control, where the CPC supplier had to work directly with the CSMS system to pass setpoint commands.

Dependence on CP back-office providers

The dependency on CSMS back-office providers was not fully foreseen at the outset of the project. Royal Mail's CP estate utilises two back-office systems (Engie's Genie Point and Swarco's e.connect). These systems and their providers are responsible for certain elements of the operation and maintenance of the CPs, such as the authentication of each charging session, maintenance of the CPs, and providing security and other firmware updates to the CPs. It was necessary to design the solution in such a way that the CSMS maintained connectivity to the CPs for these functions, without being able to over-write the control messages sent by the project's systems.

Through implementation and testing it became apparent that the CSMS has a key role in the overall solution, as failures in that platform can result in charging sessions not starting, and changes to firmware and settings can impact upon how the CPs are controlled. Optimise Prime has experienced both short-term outages, e.g. those caused by system changes that were reversed, and longer-term interruptions, such as a break in connectivity between iHost and a CSMS caused by a change in the CSMS company's communications provider. The project and Nortech has built stronger relationships with the CSMS providers in order to mitigate these issues.

There can be a complex range of actors involved in the provision of depot charging, such as CSMS providers, facility and IT systems maintainers, and it's essential to clearly define responsibilities during both the installation and operational phases.

The different elements of the charging system and depot infrastructure at Royal Mail sites were procured separately with no prime contractor. As a result, there was significant complexity such that when problems arise, it was not always clear which party was responsible for resolution. As a consequence of being active on the site, and issues occurring at the same time of testing activities, Hitachi project team members were often approached when there were disruptions to charging, but the route cause analysis found these problems were either the responsibility of the CSMS provider, or due to user error. To manage issues during the trial period, support procedures have been put in place for dealing with issues and ensuring the appropriate contractors are notified.

The use of RFID tags to identify which vehicle is using which charger is not always reliable, as tags could be swapped, get lost and replaced or drivers may not authenticate the charging session properly. Tighter vehicle and CP integration (where the vehicle itself identifies to the CP) would make optimisation of charging more reliable, simpler to implement and operate.

The charging system implemented for the Optimise Prime depots prioritises vehicles based upon factors such as their battery state-of-charge and expected schedule, as well as when there is a constraint on the site's connection. In order for this to work as planned, it is necessary to identify which vehicle is using which CP, so that the appropriate setpoints can be dispatched. In Optimise Prime this is achieved through the use of RFID identification tags that are associated with each vehicle. These RFID tags were an existing part of the CP solution and also authenticate the charging session in the CSMS back office. This is necessary because it is not possible to identify the vehicle through the CP because no communication takes place via the AC charging cable.

Through the commissioning of the solution it has become apparent that there are several issues with this method of identification that could impact the performance of charging optimisation. These include:

- While the procedure is for there to be one RFID tag for each vehicle, there is nothing physically stopping one vehicle's RFID tag being used to start another vehicle's charging session. This would associate the session with the wrong vehicle.
- While most RFID tags can only start a single charging session, each depot has a 'master' RFID card that can authenticate multiple chargers. It was found that this was often used in situations where the driver(s) had not successfully authenticated the vehicle. The 'master' card is not associated with a vehicle, so the system is not able to identify which vehicle is using which charger.
- RFID tags are sometimes lost or fail and need to be replaced. If this is not updated in the Optimise Prime system, the tag will not be associated with a vehicle.
- When new vehicles joined the fleet, or are charged at the depot, they could not be actively managed until the EV and the associated RFID tag had been registered in the Optimise Prime system.

The project took several steps to mitigate the issues related to management of RFID tags:

- Where possible, RFID tags were attached to the keys of EVs to discourage their use with other vehicles and prevent them getting mixed up
- Procedures for the use of CPs and RFID tags were communicated to drivers and through notices adjacent to the CPs
- When project team members at depots witnessed any issues, this was discussed with drivers and depot managers in order to spread 'good practice'
- Failure modes were designed into the Optimise Prime system that identified charging sessions not associated with vehicles and generated a warning, allowing the issue to be rectified
- The failure modes give a default priority to unidentified vehicles to ensure they are charged and to avoid disruption to depot operations.

In the longer term, other more reliable methods of linking vehicles with charging sessions may be needed. Using telematics to identify vehicle locations and times of charging sessions, cross referencing with CP data was considered. However, it was considered that this might not work accurately in large depots, where CPs are installed close together and many vehicles plug in at similar times, or at underground depots where there is little or no cellular data service.

The Plug and Charge standard, part of ISO 15118, is intended to allow two-way communications between vehicles and CPs. This includes a handshake process where the EV's MAC address (a unique identifier for a network connected device) is shared with the charger, providing a definitive link between the EV and the charging session. The rollout of this standard is expected to make the implementation of this aspect of the system much simpler and more reliable. Unfortunately, this could not be tested as part of the project because only a very small number of vehicles (and none of the Royal Mail vehicles) are currently capable of Plug and Charge.

RFID tags being swapped or separated from vehicles

Related to the previous point, early in testing it was found that it was a regular occurrence that RFID tags would not be consistently associated with the same vehicle. It was discovered that there was no consistent method of managing RFID tags and because many of them were cards they were sometimes taken away by drivers. To overcome this Hitachi worked with Royal Mail to replace RFID cards with RFID key fobs that can be attached to the van keys, reducing the risk of them becoming separated.

Human error in initiating charging sessions

Project teams in depots noticed that charging sessions would sometimes not be initiated correctly because drivers did not ensure that charging had started when leaving a vehicle at the end of the shift. This could be caused by a number of factors, such as not fully inserting charging cables, not fully presenting the RFID tag, or attempting to authenticate before the vehicle is plugged in. If vehicles are not authenticated, they will not charge or participate in smart charging. In Un-Managed Charging these errors were generally mitigated by the depot manager checking all the vehicles at the end of the shift. However, this is not optimal for smart charging, especially if a master RFID card is used. To reduce such incidences, additional instructional signage was provided at the CPs and advice was given to drivers when mistakes were witnessed. The system also provides the functionality of a dashboard of asset statuses and this could be provided to depot managers to allow mistakes to be rectified more quickly.

3.2.3.4 Learnings related to installation of site load monitoring

The following learnings relate to the implementation of the Panoramic Power solution used to measure electricity load on the depot sites.

Power infrastructure at larger and older sites can be complex and require additional time and resources to implement successfully

Carrying out site surveys proved essential because some of the sites were shown to have complex power arrangements requiring many more CT clamps than originally anticipated. Over the years, numerous on-site changes result in complex power feeding arrangements which were not fully understood by the depot operator. This resulted in, for example, CP units distributed over a number of electrical feeders. One site encountered had an electricity connection split across eight feeders. Some sites had a mix of high and low voltage supply and/or multiple MPANs.

End-to-end testing of systems early on is essential, as simply testing equipment on site will often not identify all issues that need to be resolved

The importance of ensuring correctly configured equipment and testing is provided by contractors was underlined by the failure to reconfigure communications devices from

Ethernet to cellular communications prior to the installers leaving site. This necessitated a time-consuming programme of device exchange by Centrica Business Services.

Wireless solutions may not be suitable for all situations

It is also important to establish a location for the bridge unit such that it can connect to the clamps whilst also simultaneously receiving a reliable cellular signal. Again, older sites can have wireless communications unfriendly locations with incoming power cables located in basements.

Measuring voltage and power factor should be considered if headroom needs to be controlled to a tight margin

When the monitoring system was originally chosen, a relatively simple solution with CT clamps was selected to monitor the current, based on the outcomes from site surveys. This system assumes, but does not measure, the voltage level at the site based on a power factor of 0.95 (a configurable parameter). It was not fully appreciated at the time how this would impact on the design of the optimisation system. Depending on the site, the power factor could impact upon the amount of the available connection capacity that is being used by the loads on the site and how much headroom is available for charging.

It was also considered that more invasive monitoring of load, with voltage monitoring, may be more costly and would likely necessitate site-wide interruptions to power supplies to enable installation – the impact of this disruption was weighed against the benefits. It was deemed that this affect would be negligible on the calculation of the required power to be delivered to the CPs.

The optimisation system ensures there is a ‘buffer’ between EV load and the calculated headroom in order to cover inaccuracies in load calculation and unexpected changes in background load of the depot. The appropriate size of this buffer will be investigated throughout the project. UK Power Networks plans to implement voltage monitoring, at the depots and substations, where possible, as part of their network-side monitoring so that any discrepancies can be identified and adherence to the profiled connection can be assessed (see Section 3.4.1).

Working at third party sites can be complex and time consuming

The complexity of installing equipment at depots for the purposes of a project is significant and should not be underestimated. Stakeholders across several functions that are not normally involved in the project, such as Property, Facilities and Operations need to be engaged, together with any subcontractors managing these functions, especially where there is potential for business interruption. The requirements and processes for contractors working on site, such as ensuring that Risk Assessment Methodology Statements (RAMS) are signed off should be made clear in advance. Where connection are made at HV locations, a ‘Authorised Person’ is required to conduct the HV work.

The complexities of monitoring load vary considerably across sites

While the same basic monitoring system was specified for each site, the complexity of the installation was found to vary considerably. This was as a result of a number of factors, such as the size of the site, its current and former uses and the age of the electrical installation. For example, one site had eight different LV cables that needed to be monitored and another had a tenant business connecting to the same supply. To properly manage against the capacity in the connection agreement, it is necessary to identify which connections the CPs are connected to. With older sites, the infrastructure may not be fully understood by the on-site teams and a survey prior to installation is essential in order to scope the work. This work requires a variety of expertise and significant time to complete.

The impact of renewable generation may need to be considered

While it was not originally intended that renewables would form part of the trials, two of the depot sites were found to be fitted with solar photovoltaic panels. It is not clear to the project how or if this will impact the overall demand at the site, and in turn the optimisation system (i.e. building load may reduce during the summer, when compared to the winter, as on-site generation covers some demand). This will be monitored further throughout the project.

Processes need to be put in place to deal with system failures quickly

The site load data feeds have generally been found to have good reliability, with low latency and consistent frequency. However, there have been occasions where building load readings for a site have stopped being received and alerting is required when this happens so that the issue can be rectified in a timely way. It has also been found that these missing readings are then filed in, post day, to correct the data. In the Optimise Prime solution this is mitigated through the buffer[4] and the development of failure scenarios. However, the impact on smart charging and profiled connections will be investigated as the project proceeds.

3.2.3.5 Behavioural and structural factors experienced at depot sites

In addition to technical issues there is significant scope for behavioural and policy factors to impact upon the operation of smart charging in depots. A number of lessons were learnt during the implementation phase that required additional actions to accommodate or modify local routines.

There may be a lack of consistent routines/policies for charging vehicles at the end of shift, and these will need to be put in place to enable smart charging

Because the trial depots were first implemented with unmanaged 'dumb' charging, there was no reason to implement uniform policies on how and when vehicles were charged, with the responsibility for the process being down to the local depot manager. As a result, there was little consistency across sites as to when vehicles are plugged in or authenticated on the chargers. With smart charging this becomes important, because it is not possible to smart charge EVs that are not plugged in. The project team worked with each depot manager to understand their process and adapt it to support smart charging. The data science team also analysed the telematics data to understand the schedules of the EV fleet in each depot.

Varying ratios of chargers to vehicles at depots

While it was originally intended that there would be a 1:1 relationship of vehicles to chargers at the depots, the number of vehicles at each location has varied over time in order to meet Royal Mail's operational requirements and as new EVs have been introduced to the fleet. As a result, some depots have two EVs per CP, while others have more CPs than vehicles. At sites with more EVs than CPs, 'alternate day' charging is used. To take account of this, the charge prioritisation methodology was designed to take into account schedules over the next two working days to ensure the EV had sufficient battery range.

[4] The 'buffer' is the amount of capacity that this removed from the agreed supply capacity of the site (or profiled connection) when calculating capacity available for EV charging, such that if there is an unexpected spike in on site consumption, at the time of a charging event, the site will then be less likely to breach its capacity agreement.

3.3 Implementation of the Trials Applications and 'end-to-end' solution

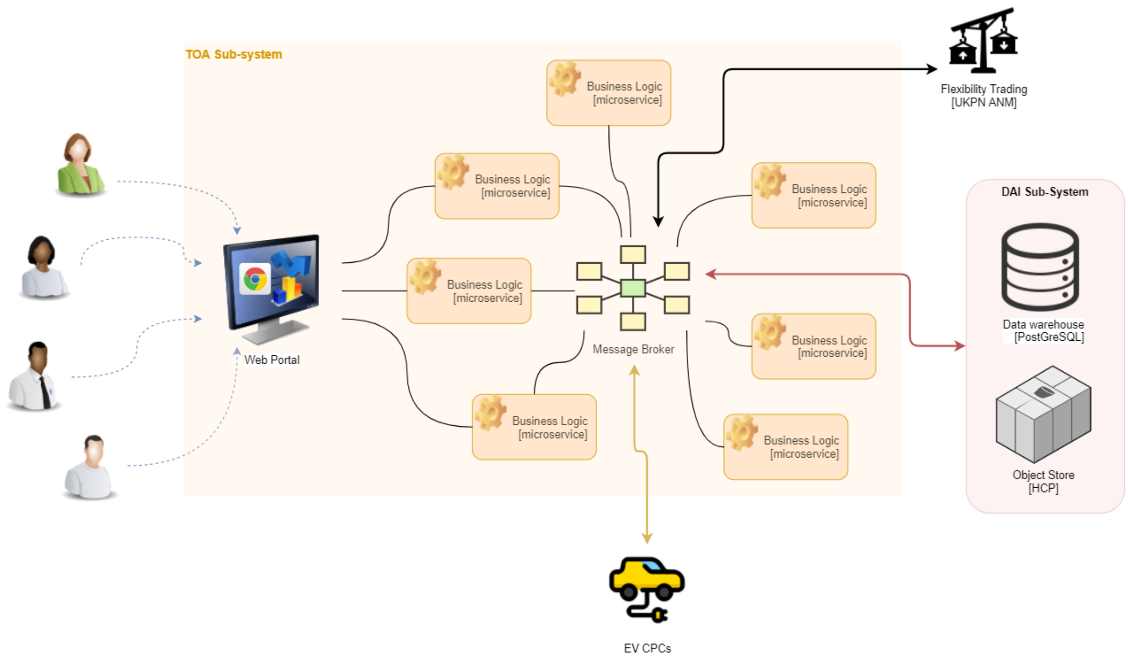
3.3.1 Overview of the trials operational applications (TOA)

The purpose of the TOA sub-system is to provide a suite of applications that will facilitate the project operational trials to be executed and monitored. Its primary objective is to enable the smart charging of EVs in Royal Mail's depots, implement Profiled Connections and to participate in UK Power Networks' Flexibility products.

Figure 12 shows how the TOA sub-system comprises an end-user web portal and a suite of software microservices to manage, balance and optimise the charging of the EVs when they are connected to the solution, via the CPs, in the Royal Mail depots. At the core of the sub-system is a message broker (Kafka) that provides the primary communication between all the microservices[5], EV CPCs and the data interface (DAI) sub-system.

The web portal will be accessed by Optimise Prime trials operators to manage and monitor the EV optimisation process. Other users may be given access to view dashboards and alerts relevant to them.

Figure 12 – High-level schematic of the TOA Sub-System



The components/microservices within the TOA applications comprise of:

1 – **Data services** – eight services take data from the web portal and external sources for use within the optimisation of charging. An asset management user interface allows users to input and update several of the data services. These cover:

- **Depot Data** – the latest specification for each depot, based on changes made in the user interface

[5] Microservices is the term to describe individual service within the application suite that together make up the full TOA solution

- **CP Types Data** – the latest specification for each type of CP registered in the system via the user interface
- **CP Data** – The specification of each individual CP registered in the system via the user interface
- **Measurements data** – the latest version of a given measure for each CP/socket, sourced via the Nortech iHost system
- **Depot load data** – the latest version of the depot load for each depot, sourced from Panoramic Power
- **Telematics data** – the latest telematics measures for each EV, sourced from the Mercedes and Axodel telematics services
- **EV data** – the specification of each individual EV asset registered in the user interface
- **EV Types data** – the latest specification for each EV Type asset registered in the user interface.

2. – **Determine CP current state** – This service compiles data in near real time to determine the most recent state (e.g. connected, charging, fault) for each CP/socket. This includes a number of data points relating to the CP and the EV connected to it and is used by several processes down the stream of data.

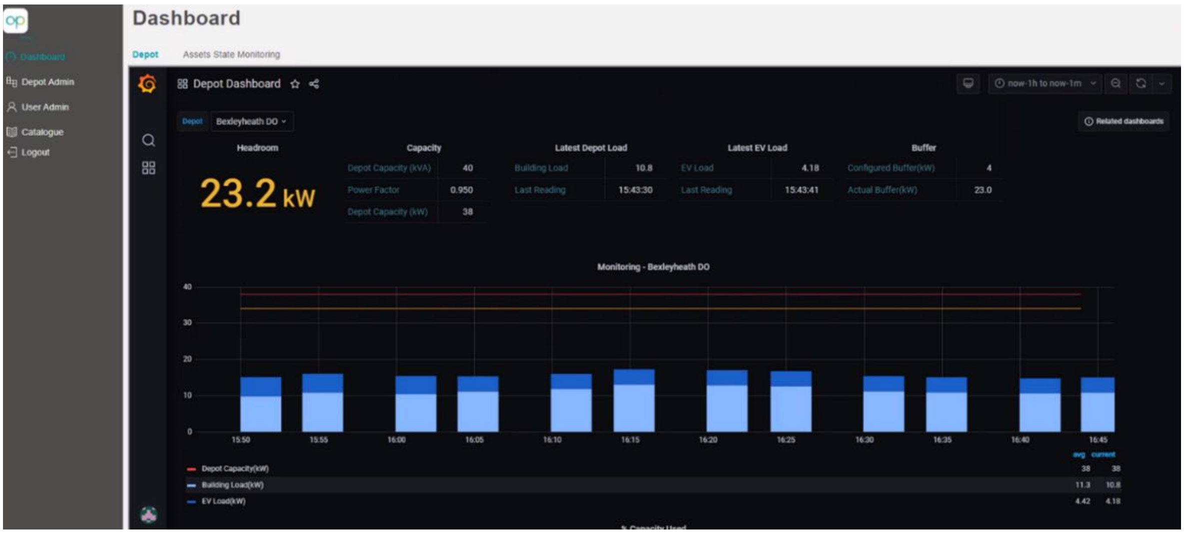
3. – **Determine Depot Headroom and Load State** – Compiles the necessary data to determine the load of each depot in near real time, thus determining the headroom available when comparing to the depot capacity at any given time

4. – **Request for Optimisation** – Based on the headroom calculated in No. 3 and the CP and EV data from No. 2, this service performs an API request to Hitachi's charge optimisation system, in order to receive the optimal setpoint to pass on to each CP

5. – **Manage CP Control Requests** – Based on the optimisation in No. 4, this service passes setpoint requests to iHost and monitors that they are correctly received by iHost

6. – **Consolidate Monitoring Data** – this service gathers, correlates and stores the data needed to monitor depots and CPs

Figure 13 – A user-facing dashboard showing current/recent load for each site



7. – **Monitor Depot & Alerting** – Based on the data stored by No. 6, this service presents a dashboard that reflects the depot load state/headroom and status for each CP/socket. Alerts will be raised based on thresholds defined in this service. Figure 13 shows a user-facing dashboard reporting depot energy use, while Figure 14 shows an example of an internal dashboard used for monitoring the frequency of system processes within the optimisation engine.

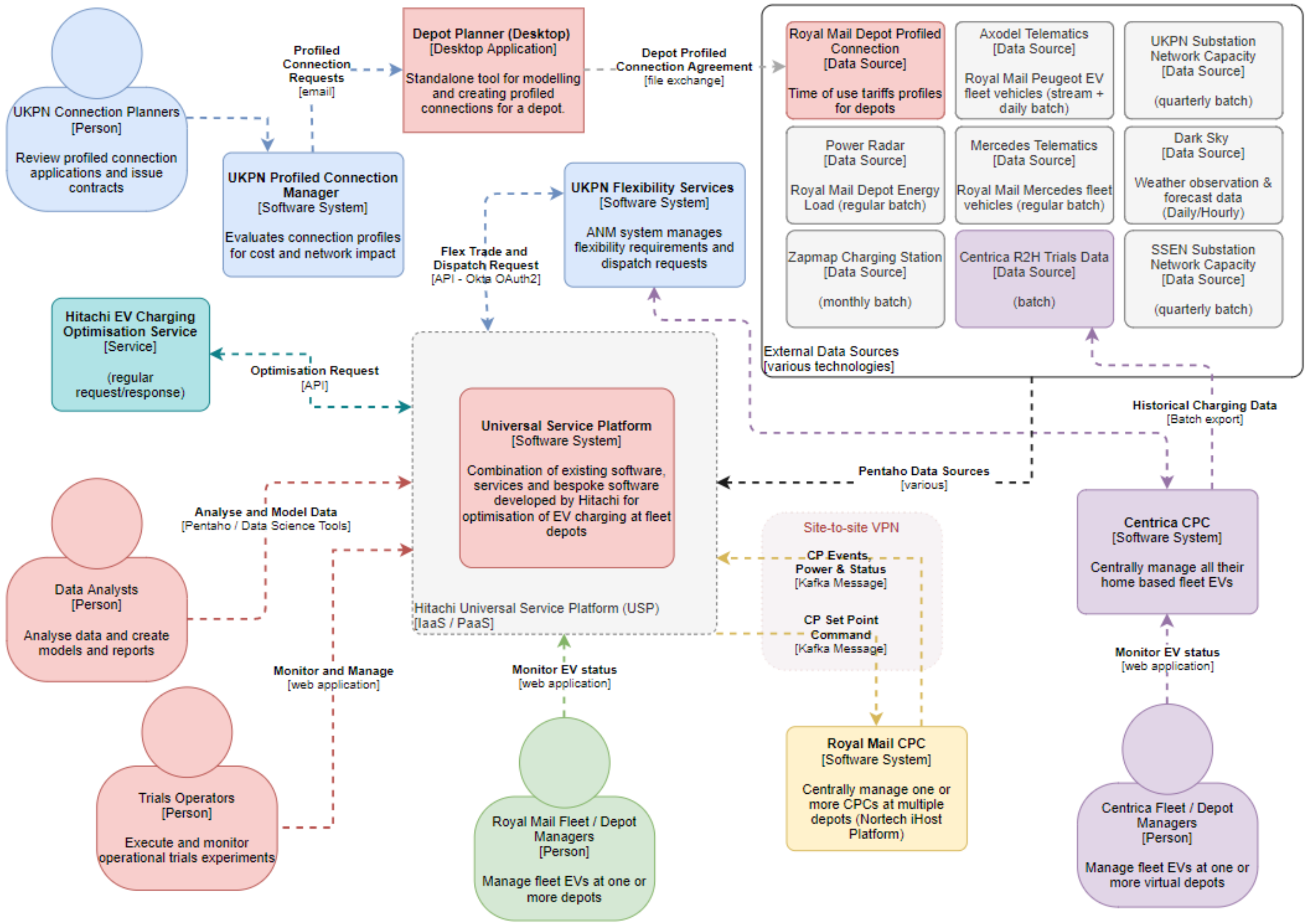
Figure 14 – An internal dashboard reporting the status of system processes

8. – **Maintain depot capacity plan** – Based on the depot connection limit and profiled connections data, this service creates a capacity plan for the depot over time
9. **– Determine EV State –** The main function of this service is to determine SoC in near real time based on telematics and vehicle data, so that this can be used in prioritisation of charging
10. **– Calculate Priorities –** This service that calculates the charging priority of each vehicle, based on SoC and schedule and passes this to the optimisation service (No. 4).
11. **– Manage Profiled Connection –** This service enables users to configure a calendar of profiled connections for each depot and pass them on for other services to use that data to perform capacity planning.
12. – **Manage Flexibility Events** – This service allows users to create Flexibility Events for each depot, either based on accepted tenders or in the form of bids, depending on the product. The service then passes them on to other services to use that data to perform headroom calculation.
13. – **Manage Electricity Tariff** – This service enables users to set times of the day/week when load should be reduced due to high electricity tariffs. This reduction can be used by the optimisation service (No. 4).
14. – **Manage Schedule** – This service allows users to set a schedule for each EV that is used in the calculation of charging priority.
15. **– Manage Prioritisation Variable Weightings –** This service enables users to configure the relative weightings of the different variables used in prioritisation, such as SoC and Fleet Schedule, in order to be passed to service No. 10 – Calculate Priorities
16. **– Configure Optimisation Options –** This service allows specified users to enable and disable services for each depot, including the user of profiled connections, flexibility and prioritisation.
17. – **Manage Flexibility Dispatches** – This service exposes a REST API that allows UK Power Networks' ANM system to issue Flexibility dispatches instructions with the real power value (W) in near real-time, within the limits of the agreed contract.

In addition to these services, a **User Management** service provides users with secure access to the platform, with permissions based on user role.

Figure 15 gives an overview of how different users and data sources will interface with the solution (the Centrica elements are not relevant to WS2, but show how Centrica's systems act as a flexibility service provider in competition to Royal Mail assets).

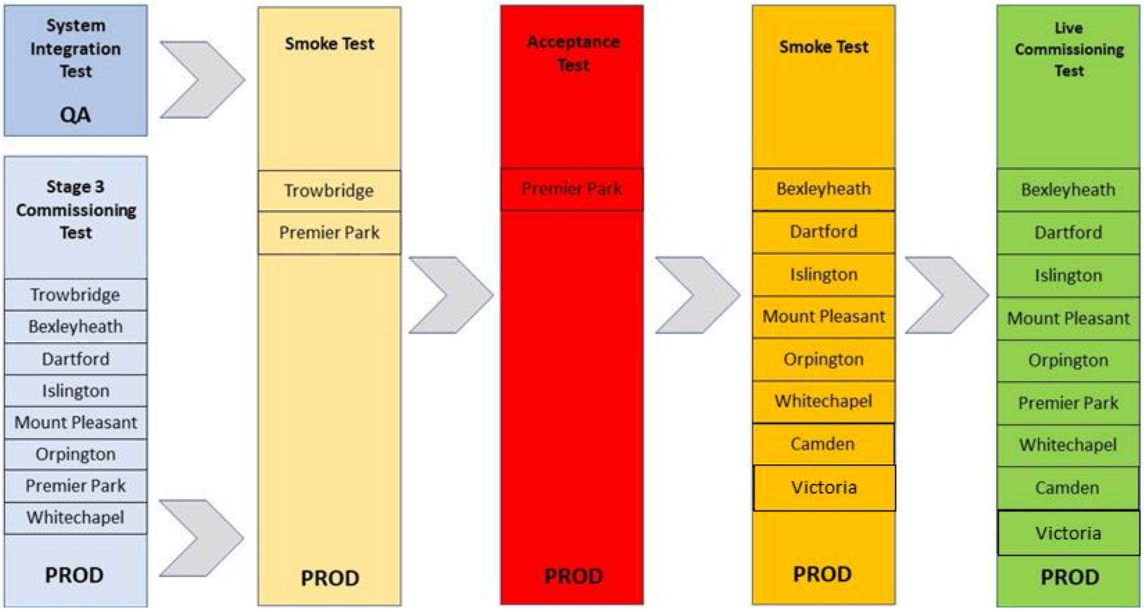
Figure 15 – TOA Sub-System Landscape



3.3.2 Testing of the TOA

The testing of the Trials Operational Applications was planned to take place in five phases, explained below and illustrated in Figure 16.

Figure 16 – Trials Operational Applications Test Phases



System Integration Testing

Once Development Testing was completed and the sprint release had been successfully deployed within the test environment, System Integration Testing was undertaken by the TOA QA Testers. System Integration Testing validated system functionality and the integration between the various technology components.

Stage 3 Commissioning Testing

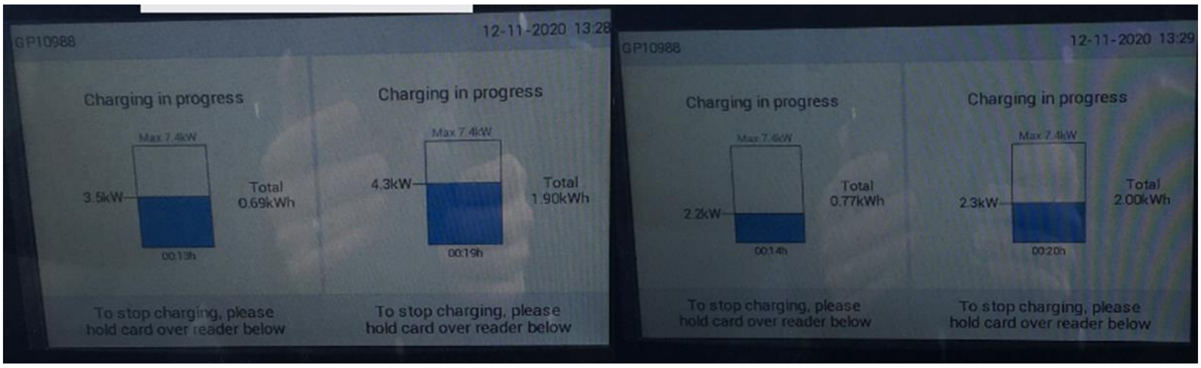
Stage 3 Commissioning Testing validated that FAT site and Royal Mail site EV charge sockets (CSs) were controllable from Hitachi's USP via Nortech's iHost platform and either the CPCs or the OTA solution (Stage 1 and 2 were tests of the depot systems that did not involve the TOA applications). Testing also validated that Hitachi's USP was able to receive telemetry for each CP using the same network infrastructure.

The tests were designed to validate the following:

- CP RFID authentication works, and that information is recorded correctly
- TOA is able to send a defined range of setpoints to each CS type at every test site.
- CPs are able to successfully enact the received setpoints.
- CP response messages are received by the Hitachi's USP.
- CP measures are sent back to Hitachi's USP.
- The latency between setpoints sent and responses received for each CS type at every test site.
- For each CS at every test site, USP is able to send a single setpoint, the CS successfully enacts the setpoint and sends a response back to USP.
- That CSMS systems can unlock a CP connector connected to an EV while communicating via the CPC to iHost.
- That CSMS systems can reboot CPs connected via the CPC to iHost.

An example of the tests that were conducted at the FAT site can be found in Appendix 9.1. The results of the tests were evidenced on site (as shown in Figure 17) as well as through review of messages and logs.

Figure 17 – Charge point screens showing a change from a 18A to a 10A setpoint based on commands from the Hitachi system



Smoke Testing

Smoke Testing was a process that determined whether the deployed solution was sufficiently stable. A Smoke Testing pack was created by selecting a number of key Acceptance Testing tests validating the following:

- Environment stability
- Availability of key systems and integrations
- High priority, core TOA functions.

Smoke Testing was undertaken:

- At the Field Acceptance Test (FAT) site following System Integration Testing completion
- At the Royal Mail Pilot site prior to commencement of Acceptance Testing
- At the Royal Mail Pilot site as required following code deliveries during Acceptance Testing

Further Smoke Testing may take place at each of the Royal Mail sites if and when new functionality is released.

Acceptance Testing

Once System Integration Testing was complete Acceptance Testing entry criteria had been satisfied, and the release had been successfully deployed and Smoke Tested within the Royal Mail Pilot site, Acceptance Testing could begin.

It was originally planned that Acceptance Testing would take place only at the Pilot site, followed by a smaller set of Smoke and **Live Commissioning** tests at each site prior to go-live. Due to time constraints and the sequencing of system availability at each site, it was decided to undertake Acceptance Testing at each site, avoiding the need for these additional testing phases.

Acceptance Testing validated TOA end-to-end functionality to ensure that the system was able to meet the requirements of the WS2 trial experiments. It validated that TOA was able to provide near real-time optimisation of energy usage within the contracted demand profile constraints using parameters derived from the following:

- Site assets
- Site Profiled Connection

- EV Telematics SoC
- Panoramic Power depot load
- CP measures
- Electricity tariff
- Prioritisation variables
- Flexibility Events

Table 8 gives an overview of the first phase of acceptance testing, carried out between 7 and 25 June 2021 at each Royal Mail site. A full list of tests and results can be found in Appendix 9.2.

Table 8 – Summary of TOA acceptance tests

Control Mode	Description	Validation
Monitor (TOA Dashboard)	The following assets were created in TOA Production environment: - Depot - CP Types - CPs - EV Types - EVs	Depot activity was monitored via the TOA Depot and Assets State Monitoring dashboards and validated the following: - Depot asset creation - Panoramic Power data feed - Nortech CP measures data feed - TOA Depot and Assets State Monitoring dashboard functionality
Test	Test mode was enabled in TOA resulting in setpoints being generated and sent only as far as the Nortech CPCs	The following were validated: - Setpoint values being generated - Nortech setpoint response return codes - Nortech CP measures data feed
Control	Live mode was enabled in TOA resulting in setpoints being generated and sent to CPs.	The following were validated: - Setpoint values being generated - Nortech setpoint response return codes - CP enactment of setpoints - Nortech CP measures data feed
Profiled Connection	A basic Profiled Connection was created for the depot.	The following were validated: - Setpoint values being generated before, during and after the Profiled Connection - Nortech setpoint response return codes - CP enactment of setpoints - Nortech CP measures data feed

Of the 42 planned tests, 37 passed, none failed and five were de-scoped as it was not possible to complete them at the time of testing. 14 bugs were raised (listed at 9.2.6); all critical rated bugs have now been remediated and the remaining issues are either in the process of resolution or were found to be due to setup issues rather than system defects.

3.3.3 Learnings from Testing of TOA and the end-to-end solution

Exploratory testing of the end-to-end solution was first undertaken at Hitachi's Trowbridge FAT site. This was followed by initial tests at the Orpington and Bexleyheath Royal Mail sites. This proved that Royal Mail site EV charge sockets were controllable from Hitachi's Universal Service Platform (USP), via Nortech's iHost platform and CPCs. Initial testing also validated that Hitachi's USP was able to receive telemetry from the charge sockets using the same network infrastructure. This early testing enabled the detection of problems and constraints in the charge control infrastructure, resulting, for example, in the need to change the Alfen charge sockets to enable one-minute reporting of power. Inconsistencies in charge socket firmware across the Royal Mail estate were also identified.

3.3.3.1 Depot Management and Optimisation

Processes are required to ensure that details of all assets are up to date

The optimisation system needs to identify all of the vehicles that it controls, in order to do this details of all EVs and CPs at a site must always be kept up to date, together with the details of all RFID tokens in use. Due to the fact that the sites did not previously utilise smart charging, management of these assets was not previously seen as an important process and as a result the process for managing RFID allocation varied significantly between depots. It took some time for the trials team to create an up-to-date registry of vehicles and related RFID cards, largely through a manual process of identifying and checking vehicles that were not recognised by the system.

Impact of variations in firmware throughout the CP estate

The Royal Mail depot CPs had been installed and updated at various times during their lives. As a result of this, the CPs used a number of different firmware versions. It was found that different firmware versions resulted in variations in CP behaviour, for example when a vehicle was unplugged and plugged back in some would keep the same setpoint while others would revert to full power charging. Hitachi is working with Nortech and the CSMS providers to update all CPs to an agreed firmware version.

Establishing the minimum controllable setpoint

While the optimisation could potentially send any setpoint to the CPs, the system is designed to not request setpoints below six amps (c1.38 kW). Sending lower setpoints can result in differing behaviour from different CPs and vehicles (e.g. the setpoint could be rejected and the previous setpoint used, or charging is paused).

Limitations on setpoint change frequency

As testing progressed, it was identified that there were limitations on the frequency of setpoints that could be received by CPs via the CPCs. Sending setpoints too frequently could in some circumstances lead to them being ignored by the CP because it was unable to process changes quickly enough, or this would cause the CP to shut down or reset. A similar problem occurred when attempting to control both sockets on the same CP simultaneously. To resolve this problem, the required frequency of setpoint request, in order to ensure compliance with profiled connections and flexibility, was analysed. It was decided that it was possible to alter the frequency of requests without adversely impacting system functionality, and so a change was implemented to send setpoints to Alfen chargers with a minimum of two seconds apart and Swarco setpoints at five seconds apart.

Loss of communications from CPs

Analysis of the data flows from the CPs identified many instances of CPs showing a ‘communications lost’ status. This was investigated and it was found that while sometimes there was a fault causing a disconnection from the CPC, it was often caused by the CP not having been used for some time and entering an Idle mode. To be able to identify CP failures an additional ‘CP status’ data field was created, and monitoring was put in place to alert system users of CP communication issues through the dashboard.

Data frequency

The Alfen chargers at Royal Mail sites had been originally set up to provide ‘Real Power’ data every 15 minutes, as an average of the previous 15 minutes. While this is adequate for simple operational monitoring, the project wanted to test optimisation and flexibility services with a more frequent data on the power being consumed by each socket. Following discussions with the CSMS provider who manage the CPs, it was identified that one-minute data could be achieved through a configuration change on the CP. This was tested successfully at the FAT site on a single CP before being rolled out across the depots successfully via a configuration change in the CSMS. However, this will use more data on the SIM card, where GSM networks are used (rather than LANs). It was subsequently found that this extra data volume could cause issues where a CP became disconnected, as when the CP came back online it would attempt to send the backlog of real power meter readings, extending the period when the current meter data is not available. Two-minute frequency real power readings are being trialled to overcome this issue.

Requirement for synchronisation of all devices to a common time server

Testing of the data feeds identified an issue with clock synchronisation across the CPs, and with the CPCs. Because the CPs were not actively having their clocks synchronised their internal clocks were slowly drifting. This resulted in some instances where messages and meter readings were being ignored by the CPC because they were deemed out of date. This may impact the ability to deliver flexibility if setpoints are ignored, or meter data for flexibility settlement delivered might be inaccurate. To solve this, the CPC firmware was updated to increase the tolerance for delayed data and the project is currently working with the CSMS provider to synchronise the clocks in the CPs.

Integration with vehicle telematics

The optimisation system takes data from vehicles via their existing telematics systems. This data is then utilised not only for analysis of vehicle use, but for near real-time prioritisation of charging in depots – a vehicle that reports a lower SoC will be prioritised to charge over a vehicle with a higher SoC when connection capacity is limited. Due to this, the vehicle telematics data needs to be reliable to ensure an optimal result.

Because the project makes use of the existing systems specified by the fleet partners (or provided with the vehicles), three separate systems have had to be integrated in order to capture the required data. Integrating the data feeds from multiple telematics systems has resulted in several learnings:

For accurate real-time optimisation all data feeds need to be in real-time

The building load feed from the each of the depots is slightly delayed, as load data is only received every five minutes (with readings for the previous five minutes at one-minute granularity). In the project this is managed by setting a buffer to cover any sudden changes in load not related to the EVs. In some circumstances, such as where site loads may vary considerably and unpredictably, a solution with real-time data may be needed.

The data requirement from telematics needs to be defined at the outset and requested from the provider

The available data from telematics can be extensive and can differ in format and content between providers. While there were benefits in understanding what data was available, the process of identifying the useful information and finding comparable metrics across the systems was time consuming for the project. Where possible it would be preferable to define the required data points first and then request the vendor's assistance in identifying the appropriate information. This may also reduce the size of the dataset created if superfluous information can be excluded.

When working with existing vehicle fleets and systems standardisation needs to be considered

It was found that, even with the same telematics system, vehicles of the same model but of different ages sometimes reported slightly different data sets. This needs to be considered when integrating existing fleets that have built up over time, and the different sub-types of EV should be identified.

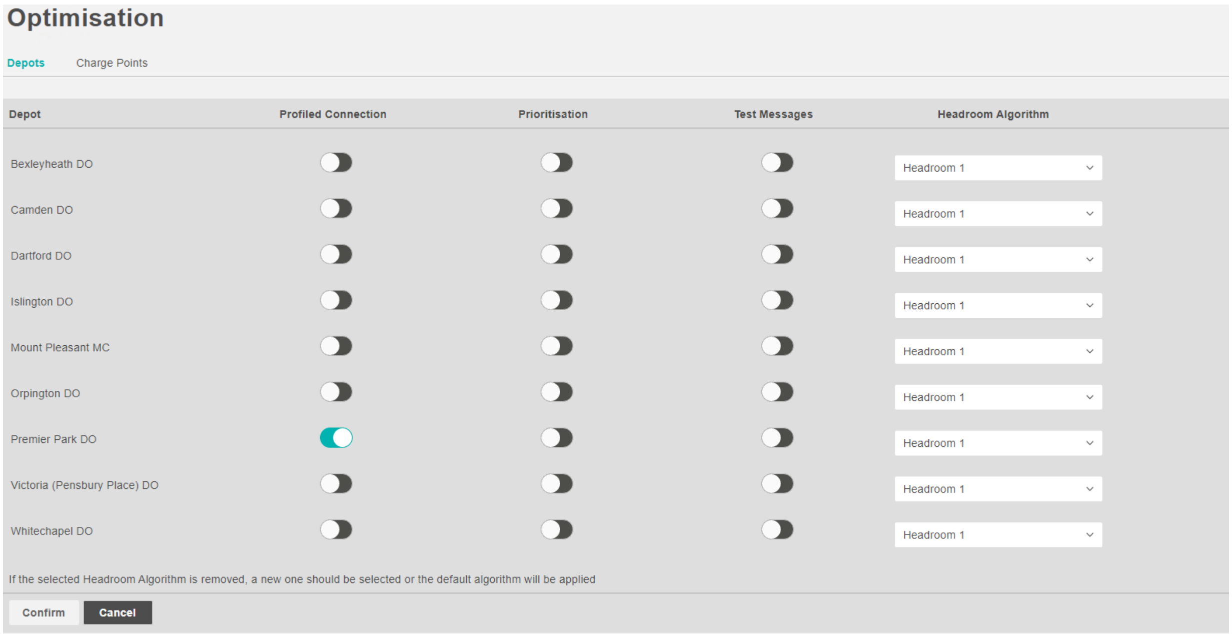
Responsibility for telematics operation and monitoring should be aligned with use of the system

In the depot trial the fleet operator was responsible for the telematics systems (as they were procured with the vehicles) but did not actively use the systems in their day-to-day operations. As a result, notifications regarding changes to services, or any errors were sometimes missed and not passed on to the project team in a timely manner. This impacted the project when changes to data sources (such as change of back-end system) only became apparent after the event, causing loss of data. This resulted in interfaces having to be re-written when the telematics system changed. Any organisation that actively uses the telematics system should ideally have responsibility for it, as they would have the motivation to ensure that any issues are dealt with quickly.

Having the ability to simply and quickly activate and deactivate overall optimisation and the different aspects of system functionalities on a depot level proved useful

As the design progressed, the benefits of developing the ability to activate and de-activate system functions on a depot level became clear and this functionality was implemented in the form of a dashboard (Figure 18).

Figure 18 – Optimisation control dashboard



This dashboard proved useful in a number of circumstances – such as during testing, where each depot can be manually switched between a test mode (where requests are sent to the CPC but not actioned) and live mode (where CPs are controlled), allowing the testing of control signals without impacting operations. During the trials, it will also be necessary to switch various functions (such as profiled connections, flexibility and prioritisation) on and off as the trial plan requires the trialling of various combinations of services at each depot throughout the trial period. Finally, having the ability to quickly deactivate optimisation, should a fault occur, brings peace of mind to the depot operator who may be worried about business impact – the ability to access this function will however by limited to specific trial personnel to prevent unnecessary interruptions to the trials.

3.3.4 Flexibility

Testing of flexibility functionalities required the integration of the WS2 TOA system, developed and operated by Hitachi as the FSP and UK Power Networks' ANM Strata system (developed by Smarter Grid Solutions – see Section 5.3.1.2 for further details of the development of this system). To enable this, an API specification was developed by the Smarter Grid Solutions team, based on project requirements, and this specification was used in the development of the interface of the Hitachi system.

The testing of the flexibility functions was completed two main steps:

3.3.4.1 Testing of interfaces between the ANM Strata and the Hitachi TOA system

This testing ensured that the systems could authenticate with each other, that messages were being passed successfully between the two systems in line with the specifications, and also tested that appropriate responses were being received when incorrect messages were sent.

Tests in this stage included:

- Authenticating the systems so that they can communicate with each other
- Sending the API messages detailed in the API specification (e.g. flexibility dispatch and the baseline/cost/deviation schedules that make up bids) and checking the contents was received correctly received and recorded
- Testing the sending and receipt of the service status message
- Simulating failure states to test the different failure state messages (e.g. Incorrect flexibility unit ID, unauthorised user, loss of comms)

Minor issues were identified where there were some variations in the implemented system from the API specification. These were raised as bugs, quickly resolved by the responsible parties and retested to ensure that the problem was resolved.

These steps were repeated for Flexibility products A (Firm Forward) and B (Day-ahead spot market), as the products have a different set of API messages reflecting their different dispatch processes. In both cases the messages were seen to be sent and received successfully, although in Product B dispatches were manually created as the optimisation function in ANM was not fully completed at the time of testing – automated testing will follow when this functionality becomes available. Learnings from the implementation of these tests included:

When developing systems that integrate with each other in parallel it is important to follow the agreed specifications closely and, where necessary agree any deviations as quickly as possible

Some changes were made to the format of the API messages expected by the ANM system that were not understood until the team prepared for testing, requiring revision of the API specification and some last-minute changes to the FSP system. It is expected that such a situation wouldn't occur in a BAU scenario as the systems would be developed in parallel.

When testing live/production systems, alternative solutions may need to be found for testing some failure states

Because the FSP production system formed part of the live TOA system connected to Royal Mail depots, the testing of some failure scenarios, such as partial or total failures of the FSP system could not be tested by switching off the whole system. Instead the failures had to be simulated by manually creating error messages or disabling parts of the system. How to test failures of this nature should be considered as part of the test plan.

3.3.4.2 End-to-end testing of the flexibility process from registration of the flexible unit through to settlement

This phase of testing was required to ensure that the technical system implemented and the business processes designed for the ordering and dispatch of product A (Firm Forward) flexibility worked together and produced the expected outcomes. This is especially important given the ability of dispatch from the ANM system to trigger changes to setpoints at operational depots.

Registration

The first part of the flexibility end-to-end process is the registration process, whereby FSPs who wish to take part in the Flexibility product A Trial submit registration details to UK Power Networks and receive a unique identifier (UUID) which is used to identify each FU within the ANM system. This part of the process is an offline manual process which ran successfully.

Pre-Delivery

The second part of the flexibility end-to-end process is the pre-delivery process. This follows on from the registration process and covers the distribution of the flexibility requirement from UK Power Networks to the FSPs taking part in the Trial; the submission of the bids from the FSPs to UK Power Networks; the acceptance/rejection of the submitted bid by UK Power Networks; and where a bid is accepted, the creation of the flexibility schedule in the TOA system by Hitachi.

This part of the process is also a manual offline process that usually occurs a month in advance. Because of this it was not completed as part of the initial system testing. This stage of the process is being tested in full as part of the project's first product A flexibility tender, which is in progress at the time of writing.

A set of flexibility events were agreed for the purpose of the test and entered into the TOA system and ANM Strata. The selection of data was based on:

- Power turn-down values that were sufficient to register reasonable payment in the Settlement process
- Depots that historically had EV charging during office hours, rather than late at night/early morning
- Flexibility periods short enough in length so as not to have adverse effects on the Production charging needs, but sufficient to register reasonable payment in the Settlement process

Delivery

The third part of the flexibility end-to-end Process is the delivery of flexibility. This covers the dispatch of the flexibility events from ANM Strata, where they are then processed in TOA, leading to turn down of the Depot's CP setpoints. Setpoints are then restored to previous levels on completion of the flexibility event. During the tests, team members observed the TOA dashboards to ensure the turn down was actioned (as shown in Figure 19), and logged messages sent between the systems.

Post-Delivery

The final part of the flexibility end-to-end process is the post-delivery process. This requires the capture of meter data from each CP in the FUs that were involved in the product A Flexibility Trial and submission to UK Power Networks, who use this to run their settlement process, which produces a report reflecting the final payment to the FSP. At the time of writing this stage of the process is still in progress.

Figure 19 – An example of a depot dashboard before (top) and during (bottom) a flexibility event, showing a reduction in available capacity (from 206kW to 5kW) and a reduction in EV load from 20.7 to 2.73kW

Outcome of End-to-End flexibility Tests

Details of the tests and results can be found in Appendix 9.3. Due to the restrictions of the test environment only two of the six pre-delivery tests could be carried out, both of which (relating to registration and bid rejection) were successful. The tests that were not completed all involved manual decision making and email messaging so were deemed low priority and will be tested as part of the trials.

Four of the delivery tests worked as expected and, at time of writing, the project team are awaiting confirmation of settlement based on meter data. However, three tests were marked as failed. In one of these cases flexibility turn down requests occurred, however there was no

EV load at the time of testing (and at one site a profiled connection test was in operation, already limiting available capacity) as a result there was insufficient capacity to meet the requirements of the dispatch. Further investigation found the lack of charging vehicles may have been due to a temporary fault in a CSMS authentication service. In two further tests flexibility down-turn was provided, however the flexibility provision was ended immediately on receipt of a zero-value command from the ANM system, while it should have ended at the time stated in the command from the ANM system (15 minutes later). A bug report was raised for this and following a fix this is awaiting re-testing.
One test, related to indication of a failure state, could not be tested and was de-scoped, as the functionality to action the failure messages was not available in the ANM system in the manual test mode. A test case for a system failure was also not carried out, as a similar test had been completed successfully as part of integration testing.

Overall, the results of the tests gave confidence (subject to the remediation of the bugs identified) in the ability of the system to activate reduced charging setpoints at the request of the ANM system. However, similar to in WS1, it also highlighted the importance of being able to predict vehicle charging activity in order to reliably deliver contracted flexibility services. The ability to accurately predict availability will be tested throughout the trials.

A similar end-to-end test for Product B flexibility has been designed and is scheduled to take place on completion of the necessary functionality in the ANM Strata system.

When testing flexibility services, multiple test windows should be used in order to identify and overcome any short-term issues

Despite scheduling tests at a time when significant charging activity was predicted, there were on occasions too few EVs, or too little controllable load, available to satisfy the requirements of the test. This is believed to be due to a combination of a temporary failure of a CSMS system and the simultaneous testing of a profiled connection. Multiple test periods should be scheduled to identify one off events and avoid them impacting results.

3.4 DNO system modifications to support WS2 trials

3.4.1 Distribution network-side load monitoring

In order to successfully implement profiled connections, the DNO needs to maintain network integrity at all times by ensuring that the agreed profile is adhered to. To check compliance with profiled connection agreements, UK Power Networks commissioned monitoring equipment at trial depots.

To provide this data, the VisNet Hub LV Monitoring solution was chosen. The VisNet Hub is a monitor that can be used to check voltage and current data on every LV feeder at a distribution substation or incoming service at customer premise, giving insight about load, faults and condition information across the network.

Figure 20 shows the VisNet Hub device installed at Whitechapel Rd GPO Parcels substation, which supplies the Whitechapel Royal Mail depot.

Figure 20 – VisNet Hub installed at Whitechapel Rd GPO Parcels substation

VisNet Hubs are integrated with UK Power Networks' ANM system to send the measurement information from sites to the central system for storage and analysis.

Steps of the process for VisNet Hub installation at a Royal Mail site were as follows:

1. Produce a Method Statement, which is a document describing the work schedules and steps that need to be taken to install the equipment at the specific site.
2. Produce site specific Risk Assessment Method, which is a document capturing the risk assessment for the work that needs to be carried out. It identifies the risk factors for a particular job relating to items of equipment to be installed/connected, access or configuration, any specific engineering challenges and how they would be managed with the use of PPE requirement, shrouding, etc. This document is complementary to the Method Statement
3. Agree installation date between Royal Mail and UK Power Networks
4. Arrange site outage for required date and times
5. UK Power Networks to arrange Council approvals/works and UK Power Networks digging/works teams as required
6. Royal Mail to arrange on-site facilities/electricians to perform specified tasks as agreed in Method Statement
7. Post Installation – provision of on-site VisNet Installation information pack to all parties.

Developing robust site-specific methodologies was essential to ensure that all the safety aspects and engineering standards had been considered and addressed in the planning, development and commissioning of the equipment. These methodologies were reviewed and approved by UK Power Networks' Asset Management and Health and Safety experts.

Learnings from the choice, installation and commissioning of VisNet hubs are as follows:

Requirement to measure both current and voltage to monitor profiled connection adherence

While behind-the-meter load monitoring at depots with the Panoramic Power solution only measures current, the VisNet Hub measures both current and voltage, to give a full picture of the power consumed by the customer. Data will need to be analysed during the trial to understand how the limitation of Panoramic Power devices may impact the successful implementation of profiled connections.

It is not always possible to install hubs within distribution network infrastructure

From the early understanding of the sites, it was envisaged that the VisNet Hubs could be installed at substations as opposed to Royal Mail depots. However, it became clear with further investigations and initial site surveys that several hubs would need to be installed at the Royal

Mail depot sites as they were not supplied by dedicated feeders from the substation. This presented unique challenges and complexity at each site requiring significant effort and visits to sites to work through the obstacles and design the work plan for each site.

Challenges of installing hubs on customer premises

The engineering design and method for installing VisNet Hubs at customer sites was new territory for UK Power Networks and the provider of the VisNet Hubs. Installing VisNet Hubs at Royal Mail depots has proven much more complex than a straightforward monitoring device installation at a cut-out point.

Installations required a large effort for documentation, process standards, safety checks and approvals, training rolled out to delivery teams. Significant complexities were encountered, and detailed site by site assessment was needed to establish tailored options dependent on unique findings at each site. Table 9 presents these specificities.

Table 9 – Specificities of VisNet hub installations at each site

Site	Site specifics	Complexities encountered	How complexities were dealt with	Learning
Dartford	Substation installation	N/A	Installation followed existing VisNet Hub installation process	N/A
Whitechapel	Substation installation	N/A	Installation followed existing VisNet Hub installation process	N/A
Camden	Substation installation	N/A	Installation followed existing VisNet Hub installation process	N/A
Premier Park	Substation installation	Vegetation blocking the way	Vegetation clearance works were undertaken prior to installing the VisNet hub	All substation installations are not straightforward, there may be additional work required to make the site suitable for installation. Getting resources available and deployed to carry out the work can take time, and therefore carrying out the first site visit early is recommended.
Bexleyheath	Royal Mail depot site installation. Asbestos issue.	Box surrounding cut-out was labelled with Asbestos warning. No service way on LV Board No consumer unit present.	Asbestos survey was carried out. Conclusion from the survey indicated that the box was clean, but cabling inside the box had asbestos coating on it. Alternative options needed to be considered for powering VisNet units involving further complexity and stricter risk measures.	Each customer connection to the network has its own unique arrangement which needs to be taken into consideration. Additional work may be required to make the site suitable for installation. Availability and access to relevant teams/specialists to give timely advice and directions on addressing the issue and giving the approvals for proceeding is complex.

Site	Site specifics	Complexities encountered	How complexities were dealt with	Learning
Islington	Royal Mail depot site installation.	• Limited options for voltage pick up location due to restricted access, which did not make it possible to apply standard methodology. • Exposed conductor was found in the break out chamber, which created a safety risk for flashover.	Alternative methodologies for voltage pick up had to be developed.	Each customer connection to the network has its own unique arrangement which needs to be taken into consideration. Additional work may be required to make the site suitable for installation. VisNet Hub should not be connected to the CT chamber as it may have an adverse effect on the metering equipment due to the extra power drawn by the VisNet Hub. Rogowski coil connections need a safe method of work defined for shrouding the terminals during the install. Introduced components (e.g. female connector) being supplied by equipment provider must be an approved product (approved by UK Power Networks' Asset Management and Health & Safety) before it can be used in relation to LV monitoring equipment installed.
Victoria	Royal Mail depot site installation.	Limited options for powering VisNet Hub due to restricted access to connect voltage leads. No service way on LV Board No consumer unit present.	Proposed method required Royal Mail electricians/facilities to cut holes in the trunking and in the busbar box to feed the cables through. Alternative options had to be considered for powering VisNet units involving further complexity and stricter risk measures	Each customer connection to the network has its own unique arrangement which needs to be taken into consideration. Additional work may be required to make the site suitable for installation. Rogowski cables to be left safe at completion of the work i.e. protected using spiral wrap or similar. Supply needs to be cut off while hole is drilled inside of busbar cabinet and cables are terminated in the top of the cut-out.

Site	Site specifics	Complexities encountered	How complexities were dealt with	Learning
Mount Pleasant	HV connected Royal Mail depot site.	HV site. LV access very limited due to compact configuration.	Site not suitable for LV VisNet installation.	Access to the LV side of an HV-connected customer for monitoring is not always possible due to limited space/compact equipment installed.
Orpington	Royal Mail depot site installation.	Complex cut out and cabling configuration which would have required lots of work as per UK Power Networks standard.	An innovative way of proceeding had to be defined to enable the works to happen, while still meeting UK Power Networks' safety standards.	Each customer connection to the network has its own unique arrangement which needs to be taken into consideration. Additional work may be required to make the site suitable for installation. Highlighted unique challenges and obstacles at customer sites strengthening the option for customer to install the equipment and connect to API to provide data required.

Responsibility for monitoring equipment installation and commissioning

The point above highlighted that each customer connection to the network has its own unique arrangement, which needs to be taken into consideration in the installation of LV monitoring at the cut-out point. This has proven highly complex. Therefore, for future trial or BAU equipment installation, it is recommended that the customer should be responsible for the monitoring equipment installation, while the DNO could provide the mechanism (e.g. API) to ensure the required voltage and current data is captured and sent to the DNO host system.

Other available options to enable customer installation of monitoring equipment could be investigated. For example, the solution adopted by Hitachi in Optimise Prime can send data for profile connections by streaming real time measurements to the ANM.

Training, documentation, safety and responsibilities/demarcation agreements in place as early as possible

Introducing new equipment such as VisNet Hubs requires detailed documentation to be developed. The project recommends for key documentation including engineering standards, safety, responsibility demarcation and training to be planned and developed as early as possible in the deployment schedule of similar trials. The engagement and mobilisation of documentation/standards needs to be planned and confirmed in advance. These activities take a significant amount of time to complete, and require the involvement of various experts who need to be mobilised early.

Investigating adapted ways to connect cables for voltage pickup measurements

Finding locations to get voltage measurements from was a challenge. UK Power Networks' Asset Management and Health and Safety standards experts developed approved designs of new solutions for voltage pick up points. Figure 21 and Table 10 shows an example of voltage pickup design developed and approved by UK Power Networks' experts.

Figure 21 – Example of an option for the VisNet Hub installation

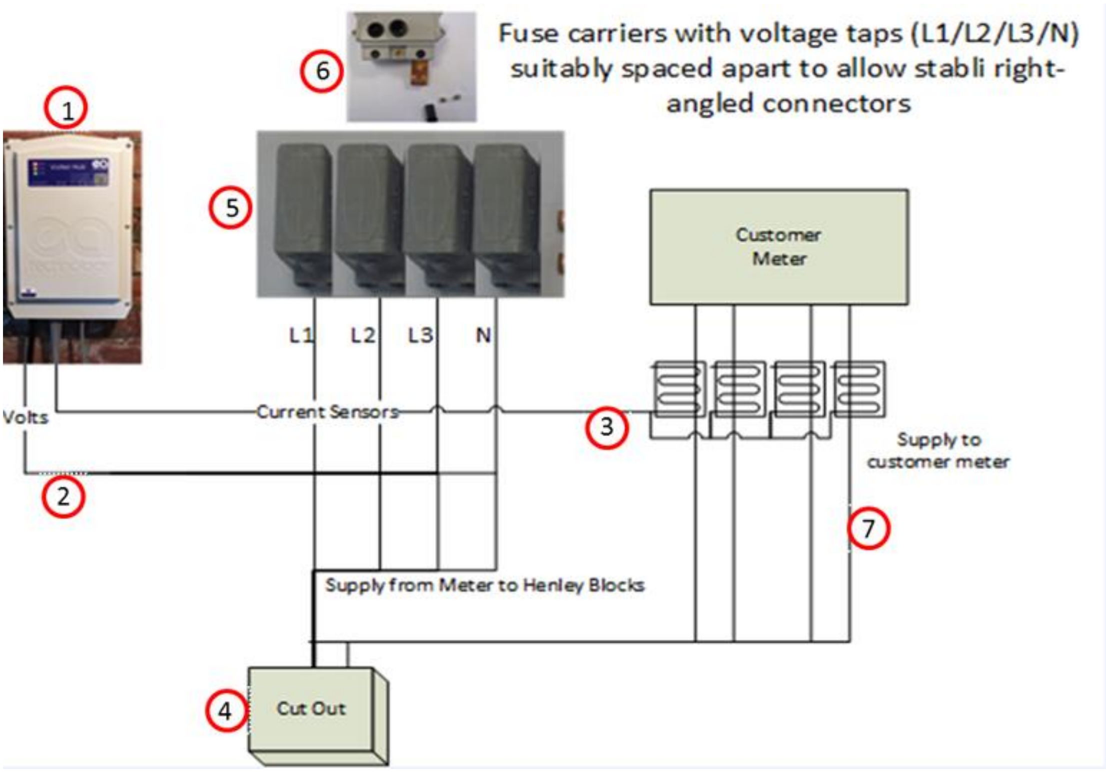


Table 10 – Key to Figure 21

Ref #	Description
1	VisNet Hub Unit 24V, 48V or no battery variant
2	Fused Voltage Lead (6m)
3	Set of three Rogowski Current Sensors (six meter lead)
4	Cut-out
5	Henley Blocks
6	Fuse Carriers
7	Meter Cable Tails

3.5 Site planning model and tool

3.5.1 Overview of the site planning model

The site planning model has been developed to estimate connection requirements of depot customers and to produce a request for a profiled connection that can be considered by the DNO.

It was decided at an early stage in the project to separate the development of the 'model' (the engine that calculates the connection request based on a set of inputs) and the tool (a more user-friendly web-based application that allows depot operators to perform the calculations themselves). The site planning model was explained in more detail in Deliverable 2.

3.5.1.1 Site planning model strategic aims

The primary aims of the site planning model is to allow the entry of vehicle schedules, mileage, site energy profiles and other constraints related to the depot such as available space, location and existing energy tariffs and output a range of information including:

- Estimated charging costs for the fleet
- EV charging schedules
- Behind the meter infrastructure requirements
- The load profiles of the site to allow for a profiled connection request to the DNO.

3.5.1.2 Data Sources & Configuration

The site planning model draws on specific data from the depot fleet operator regarding the vehicles' operational requirements, and the electrical demand characteristics of the depot site. This is supplemented with external data sources to support the analysis.

Key depot data fields include:

- Vehicle schedules
- Historical electricity consumption data per site
- Details of existing grid connection agreements (Authorised Supply Capacity – ASC)
- Electricity tariff details
- Fleet total cost of ownership details (if available)

External data to support the analysis includes:

- Vehicle specifications
- CP specifications
- Insolation values for solar generation assessment (kWh/m2)
- Battery storage and other low carbon technology (LCT) specifications

Input from the depot fleet operator is used to configure the model by defining, for each depot:

- Number of EVs to be implemented, and breakdown by vehicle model
- Number of CPs to be implemented, and breakdown of type
- Number and parameters of vehicle operational groups (departure time, return time, number of vehicles of each type)
- Capital and operating costs

3.5.1.3 Model outputs

The model outputs provide the depot operator with visibility of the potential magnitude of grid connection capacity that would be required to enable their planned fleet electrification, and whether this could be accommodated within the existing grid connection capacity. Outputs are provided across four scenarios; Base, Un-managed, EV Load Minimised and Profile Constrained Smart representing differing approaches to fleet and depot management:

This gives the depot operator the opportunity to flex the inputs to adjust the required capacity to fall within existing limits or minimise additional capacity requests.

3.5.2 Web-based site planning tool

The model has been migrated into a web-based software tool. This migration enables the model to transition from one that is designed to support the early needs of the Optimise Prime project, to a robust 'business as usual' tool for use by customers planning the electrification of their fleet.

In order to host this tool, a new environment was set up within the Microsoft Azure cloud service, enabling easy but secure access to the site for external users, as well as simplifying the future task of transferring ownership of the website to UK Power Networks at the end of the project.

To enable the development of the web-based tool, a set of requirements were specified and agreed with UK Power Networks. This was built based on experience with running the model for Royal Mail depots and an evaluation of how the model's inputs and outputs can be simplified in order to make the tool usable by non-specialists, without the need for additional support.

In particular, the web-based tool includes:

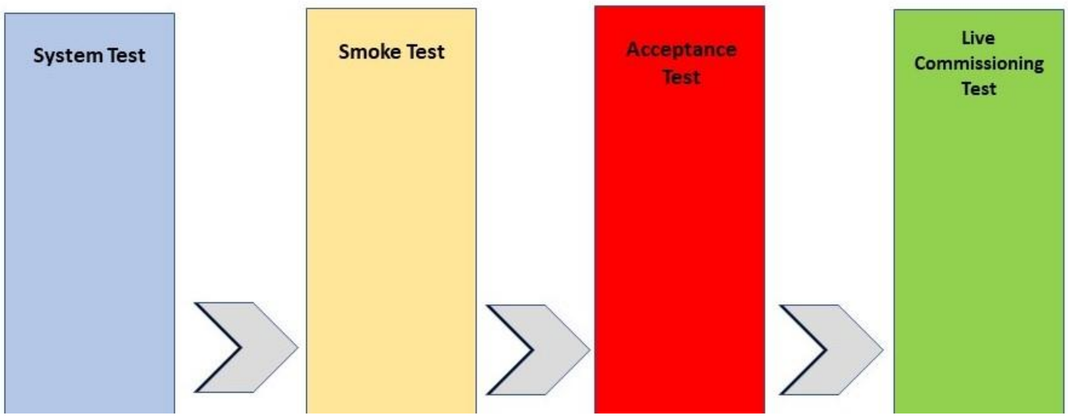
- Simplified and more intuitive user interface, allowing the user to add site 'assets' (EV, site, CP and schedule data), build 'scenarios' (combinations of assets used to simulate future depot loads) and view results of calculations. Where possible, the data needing to be updated was minimal.
- Ability to support multiple users across multiple locations simultaneously.
- Ability to reuse assets across multiple scenarios
- Ability to explore optimal configuration of site assets (in terms of connection requirement, opex and/or capex) to support development of a business case for fleet electrification.

- Ability to compare the difference in capacity required between unmanaged and smart charging scenarios.
- Ability to export a profile of site load, based on the assets modelled, that can be used to support a profiled connection application to the DNO once this product is available.

3.5.3 Approach to testing

Web-based Site Planning Tool Test Phases
Testing of the Site Planning tool followed a similar approach to testing of the TOA, as described below and shown in Figure 22.

Figure 22 – Site Planning Tool test phases



System Testing
System Testing validated the developed webpage components at an application level from a functional perspective. It validated that the Site Planning Tool allowed the entry of vehicle schedules, mileage, site energy profiles and other constraints related to the depot such as available space, location and existing energy tariffs and output a range of information including:

- Estimated depot load profiles for use in a connection request to the DNO
- Estimated charging and infrastructure costs for the fleet

The first stage of system testing focused on basic functionalities, such as being able to enter the required data, and correct validation of entries in line with the system design.

In order to test the calculation of results, several scenarios were created where the expected outputs could be calculated or estimated (Figure 23). The testing team created these and ran scenarios in the tool, comparing the actual outputs with the expectations. Where differences were identified, 'bug' reports were raised for the development team to action.

Figure 23 – Example schedule of test cases used to create scenarios in system testing

Inputs							Expected Results							
Name	Site	Tariff type	Charge Point Type	Charge Point Amount	EV Type	EV Amount	Is feasible	Base case	Unmanaged Charging	Smart Charging	CAPEX total	OPEX Total	Charging Cost	Scenario Details
Test Scenario 1	Test Site 1	Fixed	Test CP 1	10	Test EV 1 @ Schedule 1	10	Yes	120kVA	20kVA constant background load; EV load starts at schedule start and 1500 each week day at 100kVA max.	20kVA constant background load; EV load starts at schedule start and 1500 each week day at lower level (<10kVA)	n/a	n/a	Equal for both models	Reflects inputs
Test Scenario 2	Test Site 1	Fixed	Test CP 1	10	Test EV 1 @ Schedule 2	10	Yes	120kVA	20kVA constant background load; EV load starts at schedule start mon 0000 and 1200/2000 each day except Wed, Sat at 100kVA max.	20kVA constant background load; EV load starts at schedule start and 1200/2000 each day (ex Wed,Sat) at lower level (<20kVA)	n/a	n/a	Equal for both models	Reflects inputs
Test Scenario 3	Test Site 1	Fixed	Test CP 1	100	Test EV 1 @ Schedule 1	100	Yes	1020kVA	20kVA constant background load; EV load starts at schedule start and 1500 each week day at 1000kVA max.	20kVA constant background load; EV load starts at schedule start and 1500 each week day at lower level (<100kVA)	n/a	n/a	Equal for both models	Reflects inputs
Test Scenario 4	Test Site 1	Fixed	Test CP 1	1	Test EV 1 @ Schedule 1	100	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Test Scenario 5	Test Site 1	Fixed	Test CP 1	20	Test EV 1 @ Schedule 1	40	Yes	220kVA	20kVA constant background load; EV load starts at schedule start and 1500 each week day at 100kVA max, and continues twice as long as scenario 1.	20kVA constant background load; EV load starts at schedule start and 1500 each week day at lower level (<20kVA)	n/a	n/a	Equal for both models	Reflects inputs
Test Scenario 6	Test Site 2	Fixed	Test CP 1	10	Test EV 1 @ Schedule 1	10	Yes	138kVA	Background load varies 12-38kVA in Peaks. Charging starts after 1500 adding 100kW load	Background load varies 12-38kVA in Peaks. Charging starts after 1500 and	1000	10	Equal for both models	Reflects inputs

Other members of the team not involved in the development process were also encouraged to use the tool. This process identified additional areas for improvement, such as changes to the usability or appearance of the tool.

Smoke Testing

A Smoke Testing pack was created by selecting several key System Testing tests validating environment stability and high priority, core functions of the tool.

Smoke Testing was undertaken:

- Following deployment into the QA environment, prior to commencement of System Testing
- As required following code deliveries during System Testing and thereafter

Acceptance Testing

Following completion of System Testing, UK Power Networks and Royal Mail were both involved in Acceptance Testing. As depot users Royal Mail were able to provide a business driven perspective to testing, while UK Power Networks' role was to validate that the Site Planning Tool meets their requirements as eventual owners of the solution.

Live Commissioning

Following deployment of Site Planning Tool into the Production environment, Live Commissioning validated:

- Environment stability
- High priority, core site planning tool functions

This was achieved by exercising some or all of the Smoke Testing pack.

3.5.4 Outcomes from testing

Overall, the testing of the Site Planning Tool went to plan.

Initial system testing picked up minor changes required to the system's user interface and results display that were rectified quickly throughout the development process.

Further end-to-end system testing, using a range of scenarios, were successful. The main findings in this process were some discrepancies in charging cost calculations which were created as a result of vehicles starting and ending the week at different states of charge. This issue was largely resolved by setting equal target states of charge for the start and end of the week. A bug was also found in the calculation of CAPEX and OPEX which was fixed through a simple change.

Acceptance testing resulted mainly in comments regarding the usability of the tool. While the tool is relatively simple, there was felt to be a need to take the user through the steps of using the tool and to define clearly what information is required from the user. In response to this, 'tool tips' were implemented throughout all data input forms and a set of web-based help pages were developed explaining the benefits of the tool, the information required and providing a step-by step user guide. Work is ongoing to further finesse usability before the tool is launched.

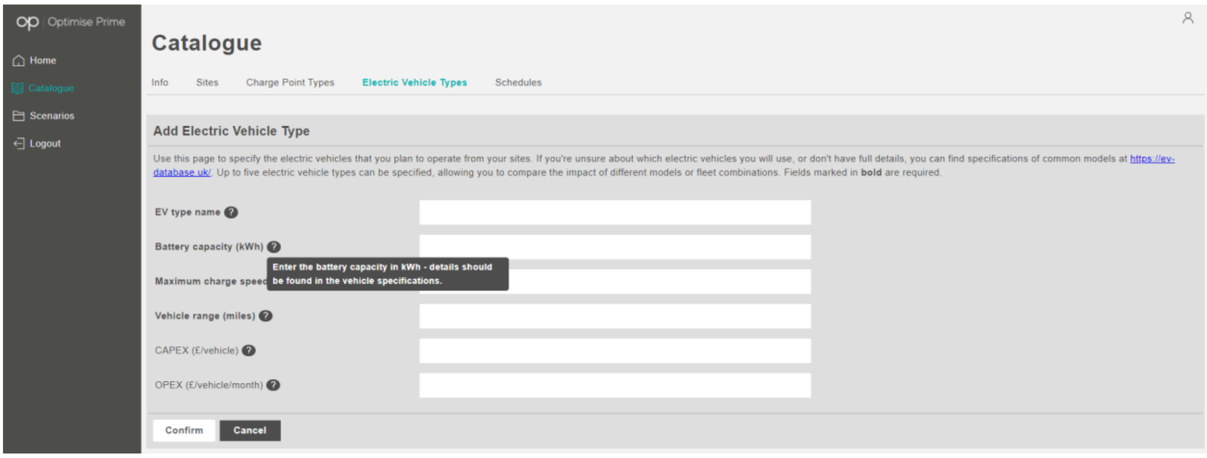
3.5.5 Learnings from development and testing of the Site Planning Tool

Development and testing of the Site Planning Tool generated several learning points regarding the design and utility of self-service tools for connection planning.

Implementing a comprehensive tool may make it too complex to use

When approaching the design of the web-based tool, all of the features of the site planning model were considered. The site planning model requires a range of inputs, such as schedules site load or on-site generation, input as large data sheets. It was decided that it was not reasonable to expect users to prepare this amount of detailed information up front in a specified format and that technically it would be difficult for a system to accept and validate data of this type. It was also decided to concentrate the design on AC charging, as allowing a combination of AC and DC capable chargers and vehicles would further complicate the tool.

Figure 24 – Example of a data input screen for specifying an EV type



As a result, the web-based system was designed to take in only the basic data required around EV charging and background loads. Due to the different ways that on-site generation and energy storage may impact upon the load at the meter point, at any time, it was decided not to include these in the web-based tool. Where possible, data is input through fields in the user interface (Figure 24), with the upload of a file only required for historical meter data. Even with this simplified data requirement it has been identified that establishing the available capacity and background electricity load may be a challenge for some users, especially those on smaller sites.

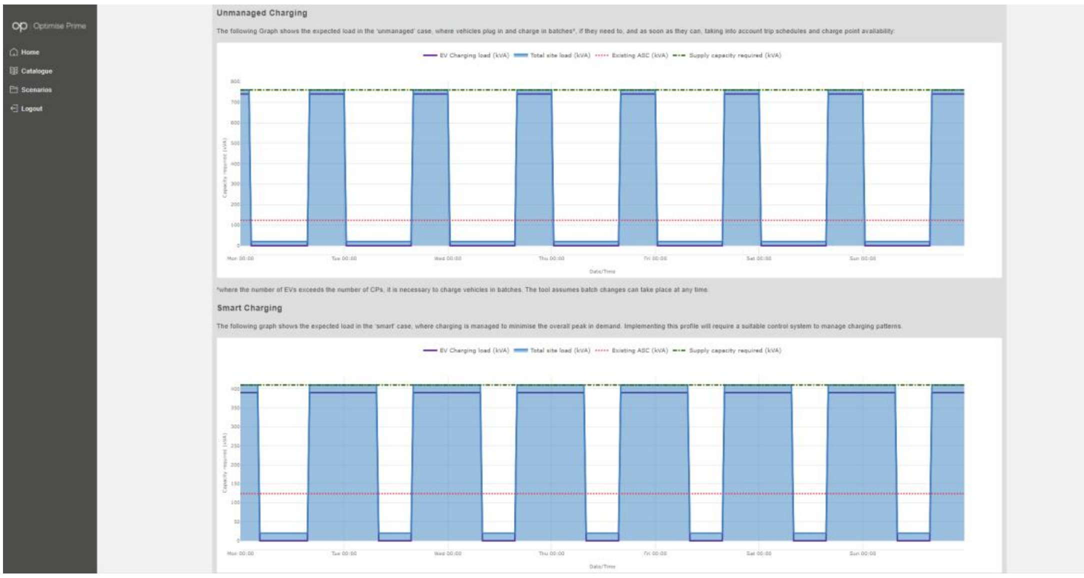
A tool of this nature can only be advisory

A significant number of assumptions need to be made in the calculation of site load, especially when it is only being displayed as a weekly or daily load curve (as opposed to a half hour format). The tool takes a conservative approach to modelling, using the worst-case background load seen in the data provided. However, in real-time smart charging, a lower peak will often be achievable. Vehicle charging is also modelled at a constant rate until the battery is full. However, in practice EV battery management systems are likely to regulate the charging speed by reducing power when the battery reaches 80%, impacting the load curve. When modelling a scenario, the tool also does not let batteries drop below 20% SoC at any time. Users need to be cautious of these assumptions and treat the output of the tool as a first step in the process of specifying infrastructure and connection requirements before discussions with their DNO.

A choice needs to be made regarding how 'smart charging' is evaluated, given the wide range of potential charging methodologies and the limited information available to the tool

In the offline site planning model, there are several possible smart scenarios, modelling to reduce peak load, to reduce cost or to keep within a pre-defined profiled connection. In the web based site planning tool it was decided to model the peak demand minimisation scenario (Figure 25), because time-of-use costs may not be known to the user (and are only an optional input to the tool) and the user would not normally have a profiled connection prior to using the tool. Indicative charging costs (based on a pence/kWh rate) can be calculated by the tool and compared across different scenarios if the user wishes.

Figure 25 – An example of 'peak load minimisation' smart charging in a simplified scenario



A more comprehensive planning tool would require significant maintenance

The tool has been designed to minimise the need for the operator to maintain the data within it. Users are encouraged to specify the EVs and CPs they wish to use in advance (and are directed to appropriate sources) and basic specifications are then entered into the tool. It was considered whether a catalogue of device specifications could be kept within the tool, but it was decided that keeping this updated in a ‘fast-moving’ EV market would be a very resource intensive task. Were the choices limited it might appear to constitute a recommendation for certain devices or may limit the accurate modelling of sites.

Creating a week or day-long view of depot load requires several assumptions to be made and this may impact results in some circumstances

An optimisation system works on an ongoing basis. However, the modelling tool only outputs a result for a representative week or day. As a result, an assumption has to be made for the SoC of each of the vehicles at the beginning of the period. In the tool all vehicles start the week at 80% SoC. This has the side effect of creating a peak on Monday mornings when all vehicles top up to 100%.

During testing, is was noted that only having a constraint at the start of the week could create an imbalance in the cost calculations, as some vehicles actually ended the week at differing states of charge. As a result, a rule was put in place for all vehicles to end the week on 80% SOC. Implementing an end-of week target also creates some issues, as some journeys close to midnight on Sunday become impossible as they would break this rule. As the tool is used the project will monitor this and consider adjustment of the parameters.

4 WS3 – Learnings from the Mixed Trials

WS3 is the mixed charging trial, a data analysis exercise looking at the charging patterns and potential network impacts of PHVs. PHVs do not have a dedicated charging infrastructure and may charge at drivers' homes or at on-street or hub based public charging points. In Optimise Prime, journey data from EVs operating on the Uber platform in Greater London is being collected and analysed. This section therefore focuses on the learnings gained from the implementation of the data ingestion (the process of capturing the data from a number of sources and storing it in a form that enables analysis), as well as from building and testing the models that will be used to analyse data during the trials.

4.1 Data ingestion

In general, the technical data ingestion process for WS3 has worked smoothly, with data from project partner Uber being received in monthly batches, and other data, such as network capacity, and CP locations being updated periodically. The only challenges faced have been in ensuring the quality of the data received, to ensure that erroneous data does not impact upon trial conclusions.

Journey data must be validated to ensure that incorrectly categorised vehicles do not impact upon results

From early on in the project, it was identified that there were sometimes cases where vehicles were wrongly classified within the data – for example an ICE vehicle being included in the data by mistake. This sometimes happened when vehicles had similar names, such as the Kia Niro and Kia eNiro. In order to mitigate this issue, a list of new vehicles and summary statistics were produced after each batch of data was uploaded, so that any anomalies, such as journeys that were too long to be covered by an EV could be highlighted. The project team would then liaise with Uber to double check the vehicle classification. This could be a time-consuming process but has resulted in confidence that the data was accurate.

The precise specification of an EV needs to be obtained in order to accurately calculate their range and charging requirements

The prediction of EV charging activity requires accurate information on the specifications of EVs – especially the battery size, range and charging speed. It was found that many EVs with similar or the same name can have varying specifications (either as a result of different vehicle options chosen, or due to manufacturers changing specifications over time). When storing vehicle data it is important to make sure that the specification is known and verified to create accurate results.

4.2 Limitations of using trip data to predict demand

The WS3 trials primarily utilise trip data from Uber's platform in order to predict where EV charging took place. This is necessary because, unlike the other two fleets, Uber vehicles are privately owned and there is no telematics solution installed. Time and location data points are received when specific events take place, such as becoming available, accepting a job, starting and ending a ride.

To overcome the limited data available, data science models were built to calculate where Uber drivers were able to charge (based on gaps between trips, locations of CPs and whether it would have been worthwhile for a driver to charge during the gap).

Some of the key challenges of working with trip data are summarised below:

Lack of battery SoC information requires assumptions and limits how weather and seasonality can be modelled

As a result of the lack of SoC data, the project's modelling has to assume the starting SoC of each vehicle each day, reducing the SoC based on trips made. As the SoC is consistently calculated, the impact on overall demand is likely to be minimal, but the prioritisation of when a driver should to charge may be impacted if the EV in fact has a lower SoC.

The impact of weather and seasonality are two variables being studied as part of Optimise Prime. Without SoC data, it is not possible to know how vehicle and battery efficiency is impacted, and what impact this has on the grid. With the data available the project can however analyse how weather and seasonality impact the number and lengths of trips and number of predicted charge events.

Data on vehicle movements is not available when the driver is not logged in to the app

The project does not have visibility of where the vehicle goes when the driver is not connected to the Uber app. As a result of this a number of assumptions have to be made about when the EVs charge and what is their SoC.

It was necessary to model 'shifts' in driving patterns to group trips together

Groups of journeys were split into different shifts when they were separated by a gap of more than four-hours. A different charging model is used for 'on-shift' and 'off-shift' charging – in 'off shift', it is presumed that a driver returns home and charges near home, traveling the shortest distance to do so. Analysis of shifts has found that while some drivers work all day many others will work in the morning and/or evening peak times only.

Home addresses of drivers were not available to the project, so locations were inferred based on journey data. A definitive view would make analysis more accurate

The home locations of drivers are not known to the project. Therefore, it was not possible to say with precision which drivers charge at home vs. using public infrastructure, and which CPs are nearest to drivers' homes. This was a known constraint from the start of the project.

To overcome this issue, it was necessary to estimate driver home locations based on where they most frequently log onto and off of the Uber app. This is calculated at Lower-Level Super Output Area (LSOA) – an area of with a population of around 1,500, and borough level so that it does not reveal precise home locations. The result of this analysis was shared with Uber, who confirmed that it was broadly in line with their understanding of driver home locations. However, there is significant scope for error as drivers may drive from their home to another area before switching on their app. To address this, a number of locations, including the LSOAs covering the City of London, Soho and Heathrow Airport were excluded from the analysis because it was unlikely that the driver would live in these locations.

It is assumed that a home location is fixed for a three-month period before being re-calculated. There are some situations where this might not be the case, such as drivers moving home, vehicles shared between multiple people or vehicles on short-term rentals. It is not thought that this will have a major impact on results, but this will be monitored as trials progress.

4.3 Integrating network data

Available data for load on distribution network is limited and more in-depth analysis is needed to find actual capacity

When first implemented the project used a dataset of maximum loads at all secondary substations and compared this against predicted EV charging load. It became apparent that this did not represent the actual capacity available for installing charger as some DNO substations (or capacity on substations) are reserved for specific users – for example those in large office buildings, or the capacity has been reserved. The project worked with the DNOs to revise the data set and exclude substations that are reserved for specific users.

Even with this change there remains the challenge that overall there is limited data on load at lower levels of the distribution network – maximum historical demand does not have a timestamp, and it is not clear if it was caused by a one-off event, demand at a specific time/on a specific day (that can be mitigated using flexibility) or a constant level of demand. Historical peak demand also does not take changes in demand into account, for example if a large electricity user moves out of an area, because it is only recorded once per year, by an engineer visiting the substation and re-setting the value

Comparison with demand forecasts can give a general picture of where the network is likely to become stressed, but more detailed analysis will be needed when planning the installation of CPs.

Network capacity constraints (and connection points for charging infrastructure) may not always be at secondary substations

It is also recognised that in some areas the primary substation, or other parts of the network may be the limiting factor, despite secondary substations appearing to have capacity. If a customer is planning to install a large charging hub (for example, multiple rapid chargers) it may also connect directly to a higher voltage level of the distribution network. These factors will be considered in the analysis of the trial results.

There is no simple way to accurately map estimated charging demand to network infrastructure at scale

When estimating charging demand, the start of journeys to CPs at LSOA level was predicted, LSOAs are small areas with roughly equal population. This was done both to anonymise the actual trip start/end points, but also to group journeys together in order to recognise trends. LSOAs do not match up clearly to network infrastructure – part of one LSOA may be served by a substation in a neighbouring LSOA, or there may be several substations serving an LSOA with varying capacities. In the initial analysis the substation with the greatest capacity within the LSOA has been compared against the charging demand, representing a mid-point between the substation with the lowest capacity and the sum of all capacity in the LSOA.

4.4 Other considerations

Network constraints are not the only factor potentially limiting availability of sufficient charging infrastructure. Available physical space for parking and installation of chargers, land ownership, and distance to the connection points are limiting factors. With regard to public infrastructure, while the project will identify areas with unmet charging demand (and consider the network impacts of meeting this), considering exactly where chargers may be installed is outside of the scope of the project.

It is necessary to separate drivers that use home charging from those utilising public infrastructure

Related to this, as the project does not definitively know where drivers live, whether the drivers have off-street parking/charging is also unknown. Based on the estimated driver home locations described above, it was necessary to assign a proportion of drivers to home charging to reflect how the demand is split across public networks and domestic connections. Initially per-borough measures of proportion on-street parking, sourced from TfL's Travel in London report, were used. On review, however, it was felt that these borough-wide averages may not accurately reflect the areas where Uber drivers typically live, and a more detailed source was sought. A dataset produced by consultancy Field Dynamics was identified, allowing the proportion of homes with off-street parking to be calculated at LSOA level. As part of the business modelling workstream, surveys are asking Uber drivers whether they have access to off-street parking in order to validate this data.

While the project uses a comprehensive public CP dataset, there is no completely accurate source, and there may be factors such as cost driving use of specific CPs

From the initial analysis of Uber journeys against public CP data, it became apparent that while the public charger data used is generally of very high quality it is not always 100% accurate. The project uses data from Zap-Map, identified by the project as the best available source, and data quality issues such as duplicate entries and lack of 'taxi only' flags have been identified. This is thought to be largely due to the fact that Zap-Map relies on a wide range of sources, including crowdsourcing, to gather its data which makes it difficult to validate all information, and because operators may make changes without notice. Where issues have been identified, these have been reported to the data provider and the project team continue to monitor for data quality issues that may impact trial conclusions.

It is also not possible to systematically exclude CPs where access may be subject to high fees (such as those located within some Central London car parks). Where possible these have been manually excluded from the analysis, where Uber have indicated that specific locations are avoided by their drivers on specific grounds, such as cost. Uber has also begun to provide charging hubs that are reserved for their drivers and these have been added to the analysis.

5 WS4 – Learnings from the implementation and testing of cross-workstream IT systems

5.1 Core data infrastructure

The Hitachi platform provides the infrastructure upon which the digital solution being delivered by the Optimise Prime team is built. It comprises both physical hardware such as compute, memory, storage and networking along with a service layer. This was described in greater detail in Deliverable D2.

The service layer provides the necessary functions for operational control, resource allocation, monitoring, maintenance, networked communications and security.

As customers of the Hitachi platform, the Optimise Prime software, data and analysis teams utilise these resources through the service layer as predominately virtualised containers. In addition to the infrastructure and resources provided by the Hitachi Platform, the Optimise Prime team benefit from a support team.

Both data centres have been commissioned and certified by Hitachi Vantara's security team and are fully operational. The operational support team (including their ticketing system) are assigned and active. Scheduled regular audit and process reviews are also in place.

The Optimise Prime Technical Authority Group also attend platform architecture and security review meetings with the appropriate members of the platform and wider USP team which meets regularly once a month or more frequently when required.

5.2 Data ingestion & analytics

The DAI sub-system encompasses data ingestion, persistence, analysis, modelling and reporting.

Figure 26 represents an overview of the various components that comprise the DAI sub-system along with the external sources that provide the data for it to ingest. The external data sources are listed in Table 11.

5.2.1 Data Ingestion

The data engineering team working on the DAI sub-system, has built a number of ETL (Extract, Transform and Load) processes using Hitachi's Pentaho Data Ingestion (PDI) tool to ingest the project's external data sources. They have built processes to ingest data from SFTP sites, Web APIs, AQMP streams, Kafka streams and from manual file uploads into the USP object store (HCP). The ingestion processes include a validation step to ensure data quality and protect against malicious content. Batch data ingestions are run on demand or as part of a planned schedule as appropriate. Streamed data is received in real-time.

Upon ingest, certain data sources are immediately published to the Kafka message broker so that they are available to the TOA sub-system in near real-time. Examples of this are the telematics data feeds from Axodel (AMQP) and Mercedes (Kafka).

The final step of the ETL process is to persist the data in both the USP object store (HCP) and the Optimise Prime data warehouse (PostgreSQL).

Figure 26 – DAI Sub-system overview

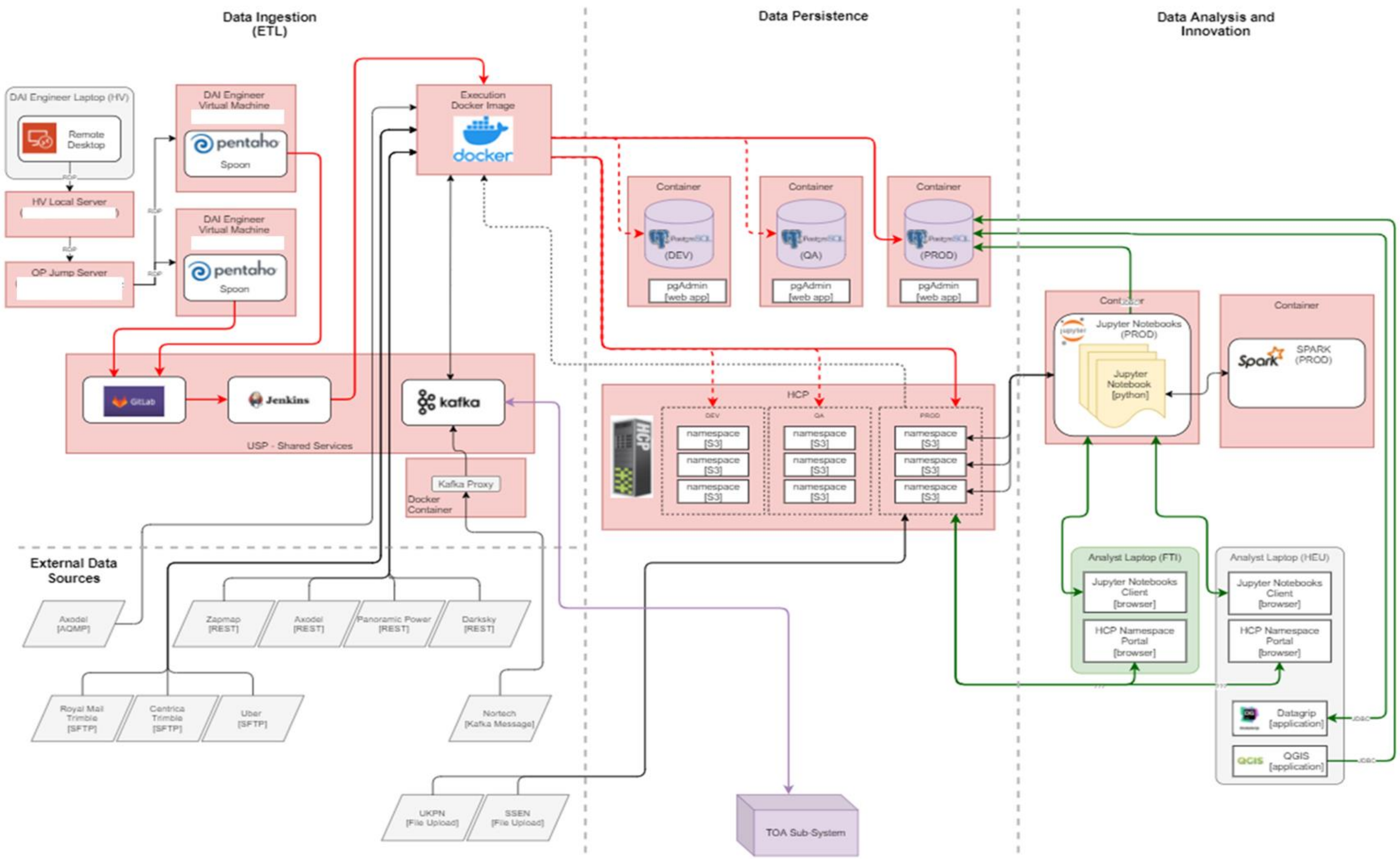


Table 11 – Data Registry Summary

Data Name	Provider	Description	Status
Uber EV trip data	Uber	Uber's EV trip data within London, supplemented with EV attributes.	Active, monthly updates
Public CP Locations	Zap-Map	Public CP locations.	Active, monthly updates
Royal Mail Telematics	Axodel	Telematics data for Peugeot EVs via batch upload from a web API	Active, daily updates.
Royal Mail Telematics	Axodel	Telematics data for Peugeot EVs via stream over AMQP service.	Active, real-time
Royal Mail Telematics	Mercedes	Telematics data for Mercedes EVs via batch upload from a web API	Active, updates every 120 seconds
Royal Mail Telematics	Trimble	Telematics for ICE vehicles via batch an SFTP site.	Active, monthly updates
Royal Mail Historical Depot Energy	Royal Mail	Historical depot energy data via batch upload from file.	Active, one-off
Royal Mail Live Depot Energy	Power Radar	Regular energy usage data via batch upload from file. Minute granularity updated every five minutes.	Active, every five minutes
Royal Mail CP Data	Nortech	Real-time EV CP measurement and status data streamed via Kafka	Active, real-time
Centrica Telematics	Trimble	Telematics data from Trimble systems installed in Centrica vans (Inc. historical from August 2018)	Active, monthly updates
Centrica CP Data	Centrica	Charging events for Centrica return-to-home fleet	Active, monthly updates
UK Power Networks Secondary Substation Data	UK Power Networks	UK Power Networks capacity data for secondary substations within London	Active, periodic upload
SSEN Secondary Substation data	SSEN	SSEN capacity data for secondary substations within London	Active, periodic upload
Observed Weather data	Darksky	Observed weather data for London via web API.	Active, daily update
Weather Forecast	Darksky	Weather forecast for London via web API	In Progress, hourly update

5.2.2 Data Analysis and Reporting

The analytics system is built on and around an engineering solution: a Jupyter Notebook frontend provides a Python-based environment for Data Analysis and Data Science, and a custom-built Python library provides connector functions enabling the environment to interface with the backend persistent storage solutions (Hitachi Content Platform and PostgreSQL). Further, analysis is version-controlled and backed up in Gitlab, which allows analysis to be tracked over time and enables reversion to previous versions if required.

To date, this toolset has been used to complete a number of pre-trial experiments across the WS1-3 workstreams. In WS3, where trials have begun, analysis has been completed outlining inferred locations and frequency of charging events from Uber EV drivers. This inferred charging demand has also been correlated with available 'headroom' (i.e. available capacity) in the electricity distribution network.

5.2.3 Modelling

The Royal Mail and Centrica datasets have been used to create predictive models for estimating likely charging demand from an EV fleet, based on telematics data from an equivalent ICE fleet. This model will be further extended and refined using actual data from EV telematics and CPs. Modelling based on Uber data has focussed on predicting charging locations, and scaling up the current EV data set to model future demand.

5.2.4 Learnings from implementation and testing of the DAI

Risks from reliance on third party data sources

As described in Section 5, the major challenge to data ingestion has been the reliance on third party data services, especially in cases where the project is not directly contracting the provision of the services and does not always get timely notifications of changes and outages. For example, with two of the telematics providers the project encountered data outages when suppliers either changed the format of data, or the hosting of their telematics platform. A similar event occurred when one of the CSMS providers changed the provider of their IT infrastructure, resulting in a loss of connectivity between iHost and the CSMS platform. These events resulted in additional time for the Technical team to make changes to the data ingestion processes.

Requirement for monitoring and alerting of services

As highlighted by the above incidents, monitoring and alerting when data feeds stop responding, or provide erroneous data is a key requirement, especially where that data is feeding into automated optimisation processes. As part of the trials applications, daily reporting of key statistics was implemented, together with active alerting when data is not received – allowing project teams to identify and rectify or mitigate problems as soon as possible.

5.3 DNO systems integration

In support of the trials, UK Power Networks have developed a number of alterations to their systems and operational processes. This allows the project to test provision of flexibility services with processes based on the business-as-usual flexibility systems. UK Power Networks has also made enhancements to modelling tools to make use of the data generated from Optimise Prime for planning of future network enhancements. SSEN has also developed a manual process for testing flexibility response in their network area, which could potentially be used as an offline backup system. The following section provide more detail on the lessons learnt from these developments.

5.3.1 Active Network Management system alterations to enable the Optimise Prime flexibility products

Optimise Prime will demonstrate two operational methods of smart EV charging – these operational methods are referred to as “schemes”:

- **Profiled Connections**, where fleet depot sites must follow a pre-agreed profile of import limits; and
- **Flexibility Services**, where fleet depot and home fleet EV charge points provide commercial demand turn-down services. Flexibility Services is broken down further into three different Products:
    - Product A: Firm Forward Option
    - Product B: Spot Market
    - Product C: Balancing Market

The four distinct schemes defined above each have unique ANM testing requirements based on the functionality which is being delivered. As such, testing was carried out in four separate cycles, one for each scheme.

5.3.1.1 Profiled Connections

Table 12 describes the different ANM tasks that deliver the profiled connection functionality.

Table 12 – ANM functionalities for profiled connections

Use Case	High-Level Description
Measurement Update (DNP3)	Process which ANM Strata will use to gather live measurements from the VisNet Hub located at the FU using the DNP3 protocol.
Compliance Monitoring	Process which the ANM System uses to monitor the FU for compliance against the dispatch command or demand profile.
Demand Profile Expiry Monitoring	Process which the ANM system uses to monitor demand profiles for expiry.
Update Demand Schedule	Update of a demand schedule for a FU by the DSO user. The availability schedule is stored within the ANM System and can be downloaded for transmission to the FSP.
Upload Demand Schedule	Upload of a demand schedule for a FU by the DSO user. The availability schedule is stored within the ANM System

5.3.1.2 Flexibility Services

Table 13 describes the ANM tasks that deliver the Optimise Prime flexibility services trial functionality with Product A.

Table 13 – ANM functionalities for flexibility services – Product A

Use Case	High-Level Description
Registration of FSP	The market platform provides the ability for users to register as FSPs. Once this registration is complete the FSP will be able to register DER and participate in markets.
Registration of DER	An FSP must register its DER in order to propose them in the response to a tender request.
Respond to Tender	Once an FSP User has DER registered on the Market Platform, it will be possible to use them to respond to tenders which have been created by UK Power Networks. Once the FSP has responded to a tender it will be necessary to go through the tender approval process before this tender can be approved and then added to ANM Strata as a FU.
Upload Demand Data	This Use Case describes the functionality which allows an FSP to upload historical demand data to the ANM Solution.
Dispatch Single Window	This use case describes the process which ANM Strata carries out in order to issue a single window dispatch command to an FSP. ANM Strata will select the single window from the dispatch schedule which is currently configured for the FU. ANM Strata selects a dispatch value for a time in the future based on a configurable "time ahead" parameter.
Authenticate with FSP (OAuth2.0)	OAuth2.0 has been chosen as the authentication method for requests initiating in ANM Strata and being issued to the FSPs. This method requires ANM Strata to request an authentication token from a third party specified by the FSP and then utilise this token. This Use Case describes the process ANM Strata carries out to manage this token.
Upload Load Forecast	Upload of a load forecast by the DSO user. The load forecast is used by the optimisation algorithm to determine the dispatch schedule for the FU.
Upload FU Availability	Upload of an availability schedule for a FU by the DSO user. The availability schedule is used by the optimization algorithm to determine the dispatch schedule for the FU.
Create Manual Dispatch Schedule	Creation of a manual dispatch schedule for a FU by the DSO user. Once this schedule has been created the DSO user can configure ANM Strata to dispatch these values to the FU.
Select Dispatch Schedule	ANM Strata allows for a number of dispatch schedules to be created for a FU – it is necessary to choose which one is to be dispatched. For Optimise Prime there generally are two schedules which are available for dispatch: • Manual Dispatch Schedule: The schedule manually entered by the DSO User. • Optimise Dispatch Schedule: This is the schedule output by the system optimisation.

Use Case	High-Level Description
Settlement	Gather the data necessary for the Settlement process. This data is located across a number of different sub systems within the ANM Solution so it needs to be gathered from the different sources and collated in a manner such that it will be useful in the UK Power Networks designed settlement process.
Compliance Monitoring	Real-Time monitoring and non-compliance are failsafe responses designed to raise alarm notifications and prevent issues associated with a FSP failing to respond to a control request issued by the ANM System. For the Optimise Prime trial this will only be applicable to the Royal Mail depots where the full depot real time demand is provided to ANM Strata via the VisNet Hub.
Detect Communication Failure to Measurements	ANM Strata will gather site measurements from a VisNet Hub located at the FU and must detect when this communication link has failed. ANM Strata will periodically check these measurement values. If ANM Strata has not received a measurement update for a time greater than the measurement timeout then it will flag a communication failure to this VisNet Hub.
Measurement Update (DNP3)	Gather live measurements from the VisNet Hub located at the FU using the DNP3 protocol.
Product A Dispatch	Carry out dispatch for Flexibility Services Product A. This dispatch involves the monitoring of the configured dispatch schedule and every 15 minutes issuing a new dispatch command for 30 minutes ahead.
Product A Optimisation	The goal of the optimisation problem is to find the flexible unit dispatch schedule which meets the predicted target load levels at minimum cost. The resultant dispatch schedule consists of a dispatch setpoints, specifying how much each flexible unit will be dispatched.
Update Baseline Value	The baseline calculation is performed by the ANM Strata in order to provide some insight into what the FU would be importing if it wasn't being utilised for a flexible service. This is achieved by performing a calculation on the historical measurement data for the FU. This use case describes the "Recent History" process.

Table 14 describes the ANM tasks that deliver the Optimise Prime flexibility services trial functionality with products B and C.

Table 14 – ANM functionalities for flexibility services – Products B & C

Use Case	High-Level Description
Contract Information	Contract details are configured on to ANM Strata when new FSPs are configured onto the platform. This is carried out by the Optimise Prime User.
Automated Dispatch schedule	ANM Strata allows for a number of dispatch schedules to be created for a FU. For Product B and C, the dispatch schedule will be auto-generated by the Optimisation engine based on input data.

Use Case	High-Level Description
Submit Schedule	This use case describes the process of submitting a schedule via the ANM Strata UI by the FSP User. Schedules are submitted via API.
Submit Baseline Schedule	FSP user submits a baseline schedule to confirm their expected baseline demand profile from midnight to midnight for the following day. This can be done via the API or by logging in via the ANM Strata UI. Baseline is provided as Watts for each 15-minute period for that particular trading day e.g. 96 periods from midnight to midnight. A 30-minute frequency can also be configured.
Submit Cost Schedule	FSP user submits a cost schedule to confirm their expected costs for provision of a demand service. This schedule covers the period midnight to midnight for the following day. This can be done via the API or by logging in via the ANM Solution UI. Cost is provided as £/MWh for each 15-minute period for that particular trading day e.g. 96 periods from midnight to midnight. A 30-minute frequency can also be configured.
Submit Deviation Schedule	FSP user submits the available deviation of the FU via ANM Strata using the specified API. Deviation availability is how much the FU is able to reduce power during that HH period away from the Baseline Schedule. This can be done via the API or by logging in via the ANM Solution UI. Deviation availability is provided as watts for each 15-minute period for that particular trading day e.g. 96 periods from midnight to midnight. A 30-minute frequency can also be configured.
Product B Automated Dispatch	Dispatch for the FU is configurable based on the market requirements. For Product B, the Dispatch Schedule is issued to the FSP at some time ahead of the required delivery date. For example on Monday at 2000hrs, ANM Strata will send out the dispatch schedule for Tuesday, consisting of either 96 15-minute or 48 30-minute periods, starting at 0000. Time ahead settings can be configured as required during configuration.
Product B optimisation	The goal of the optimisation problem is to find the flexible unit dispatch schedule which meets the predicted target load levels at minimum cost. The resultant dispatch schedule consists of a dispatch setpoints, specifying how much each flexible unit will be between zero and its stated availability for the time slot in question.
Product C Automated Dispatch	Dispatch for the FU is configurable based on the market requirements. For Product C, the Dispatch Schedule is issued to the FSP at some time ahead of the required dispatch period. For example, on Monday at 1200hrs, ANM Strata will send out the dispatch schedule for Monday 1400-1500. Time ahead settings can be configured as required during set-up.

Use Case	High-Level Description
Product C optimisation	The goal of the optimisation problem is to find the flexible unit dispatch schedule which meets the predicted target load levels at minimum cost. The resultant dispatch schedule consists of a dispatch setpoints, specifying how much each flexible unit will be dispatched.

5.3.2 Developing a methodology for offline testing of flexibility services in areas not served by UK Power Networks' ANM

To avoid duplicating effort in testing flexibility services via integration with a second DNO's ANM (SSEN also utilises ANM across its licence areas) SSEN offered to develop a means of testing flexibility services across Products B and C with Centrica in an offline scenario, i.e. should there be issues with communications or a particular system such as automated flex dispatching via the ANM, could a manual process still allow the necessary flexibility to take place?

This potential resilience should only require a small amount of testing to provide the viability, and it is not designed in any way to be anything other than a redundancy feature for use in rare events.

That being said, it is still important to ensure not only would the process for requesting/dispatching of flexibility still be viable, but that the assets (EVs) would still respond to a number of scenarios deemed essential for a DNO.

As a result, SSEN drafted a process building on the Optimise Prime Flexibility High Level Design and Optimise Prime Product Design documents. This drew out the key steps needed for the two differing trials (Products B and C) to ensure that it matched the steps to be taken in the trials utilising UK Power Networks' ANM albeit in a simplified and manual process using email. Considerations were given to double-checking communications were received and acted upon in lieu of system automation, and so steps were added with the objective to confirm and validate actions using email (and phone calls if required). This has been shared with Centrica and is undergoing review for feasibility for a short trial to demonstrate the effectiveness of the process.

In designing the schedule for testing, SSEN considered the potential drawbacks of using Centrica's assets which may be spread across large geographic areas and so would be unlikely to be able to offer ability to test demand reduction on a specific individual section of the network, which is what SSEN are most keen to evaluate the potential for. As a result SSEN decided that once the aggregation of assets was carried out and Centrica shared the details of these FUs, work would be done to create pseudo-networks to consider the testing of different FUs and what level of response could be achieved across different parameters. As a result a range of key features to test against a commercial fleet were drafted by SSEN to assess against a range of scenarios, covering aspects such as potential for afternoon peak demand reduction, evening peak reduction, overnight peak reduction, and reduction from every asset in response to a major event. The specific details of this testing plan has not been shared with Centrica with the aim of maintaining an element of real-world interaction. The hope is that these scenarios can be tested across Products B and C using the manual process to demonstrate that with a few simple steps there can be sufficient resilience in flexibility systems should there be a failure somewhere in the use of automation.

6 Approach to testing and quality assurance

In developing the Optimise Prime systems, the project developed a Quality Assurance (QA) Plan in order to ensure that quality of delivery is assured across the full solution. This section outlines the main aspects of this plan.

A QA Manager was recruited in November 2020 to support the project management function in this role. The QA Manager implemented the Quality Assurance Plan together with a Test Strategy which detailed the approach being implemented to assure both the Trials Operational Applications and Site Planning Tool deliverables on their journey from development to production. The test phases for each deliverable are outlined in this section.

The primary tool that was used to track the quality assurance of the Optimise Prime project was Target Process. Target Progress is an online web application that was used by all teams on the project to manage:

- **Creation of Test Plans** – A set of test cases, which is created to test specific functionality or for repeating testing activities. A test plan allows the reuse of tests and can be executed multiple times (e.g. during regression testing when new functionality is added).
- **Test Plan Runs** – The execution of a test plan. A test plan run was created each time a test plan was executed. Multiple test plan runs were created for each test plan.
- **Creation of Test Cases** – Used to test a specific piece of functionality. It has a description and a set of test steps. A test case was part of many test plans and executed multiple times.
- **Test Case Runs –** The result of a test case. A test case run was automatically created with a test plan run. There were many test case runs for each test case. Related bugs were created whilst executing test cases.
- **Addition and Tracking of Bugs** – Capture, add, classify and prioritise bugs which allowed functional to be managed and fixed.
- **Triage Bugs** – Visual boards were used to spot bugs with high severity and high priority.
- **Track Quality Trends** – Visual reports on metrics for bugs being created and closed were used.

QA is applied at all levels across the Optimise Prime technical solution and direct responsibility for its implementation was assigned in the quality assurance plan.

6.1 Programme and Team Level

Within the project, QA activities were also managed by each work stream.

6.1.1 Trials Management (WS1, WS2 and WS3)

The project's QA processes extend beyond the development of the solutions and cover the execution and reporting of the trial experiments in order to ensure experiments are conducted in a consistent manner and properly documented.

6.1.1.1 Experiment Execution

QA within experiment execution covers four stages:

- **Experiment Preparation** – the trials management team will confirm that all necessary pre-conditions are in place (e.g. technology and software is set up to capture data, external datasets are available, any operational conditions such as driver approval are met). When all is in place, approval to launch the experiment will be given.

- **Experiment Operation** – the trials management team will confirm that data is being captured across the expected fields as defined in the Success Criteria for the experiment. If data is not captured across the expected fields, the experiment will be halted and redesigned.
- **Experiment Analysis** – where relevant, a sample output from any data manipulation or analysis process will be compared with an output from a separate system (e.g. Excel model) set up to conduct the same analysis.
- **Experiment Conclusion** – the trials management team will confirm that the required experiment iterations to meet project statistical relevance objectives have been conducted and data successfully captured. When this is the case, the trials team will grant approval for the experiment to be closed.

6.1.1.2 Experiment Reporting

Quality Assurance within experiment reporting focuses on ensuring the experiment results satisfy the aims of the relevant objectives and sub-objectives. The trials management team will confirm that the results reported enable the experiment hypothesis to be confirmed or rejected. They will also confirm that this outcome is sufficient to satisfy the relevant sub-objectives associated with the experiment.

If results are inconclusive, or it is found that the results of this experiment, together with associated experiments, will not meet the aims of the sub-objectives and objectives for the trial, the experiment will be redesigned and repeated.

6.1.2 Technical Delivery

Technical teams involved in software and data engineering were responsible for testing solutions throughout development, before they are released to UAT.

6.1.2.1 Software and Data Engineering

The software and data engineering teams followed similar QA processes and so they are described together here.

Quality Assurance within software and data engineering can be considered in three specific specialist areas within the team and their software/data delivery lifecycle (SDLC/DDLC). They covered all stages within the SDLC and DDLC from the lowest level of code units up to full-system integration.

- **Unit Testing** – Specific to the Software Engineering discipline, the software engineers implemented unit tests at the code “unit” level that execute automatically on every build. Associated with each unit test was a set of control data, usage procedures, and operating procedures that were tested to determine if the code was fit for use before deployment into the software integration environment. This activity took place within the Development Environment.
- **Integration (Automation) Testing** – Automated integration testing was used to validate the behaviour and functionality of the software/data system when the code modules (ETL scripts, microservices, web applications, APIs, etc.) were connected together. These automated tests were designed, created and managed by a dedicated Automation Test Engineer and were based around end user scenarios and representative datasets. This activity took place within the QA Environment.
- **Functional (Manual) Testing** – This activity involved a Dedicated functional (Manual) tester who completed scripted manual testing of data ingestion processes, user

interfaces and APIs. Repetitive tasks were moved to Automation Testing where possible. The tester provides the final sign-off before delivery of the solution into the Production Environment. This activity took place within the QA Environment.

The QA process was as follows:

- User Stories were created that outlined the business value to be developed into the DAI or TOA sub-system
- The QA function was involved in the User Stories refinement, so that a shared understanding of the objectives of each of the stories exists between Development and QA. At this stage QA team members also refined the stories, contributing with validations
- Based on the User Stories acceptance criteria, a set of test cases and scenarios were identified that allowed for testing of the User Story and determined its successful completion. These cases and scenarios were recorded in Target Process
- Once the development team finished the User Story development, the new code is deployed to the QA environment
- After this, the QA team performed a test execution for the scenarios previously created. The results of the test execution were recorded into Target Process.
- For all bugs identified, the QA team recorded them in Target Process and communicated them to the development team
- After bugs were corrected, the test scenarios were executed again. This cycle happened until all test cases had passed. At this stage the new development was ready to be promoted to the Production environment
- After the new development was successfully completed, automated regression testing was developed, which allowed a retest of the component in a much more efficient way, without the need for manual re-testing.

6.1.2.2 Data Analysis Methodology

The Data Science approach for QA built upon principles of the Software and Data Engineering approach. For each data analysis, core code abstractions that represented functional capability were integrated into a centralised, version-controlled code base/library and were unit/integration tested where applicable. Notebooks summarising the data analyses (e.g. Experiment Execution) were manually tested and committed to the code library, with full documentation. Target Process and Gitlab were the tools used to track and version the data analysis. Documentation was tracked and versioned through Gitlab and Confluence. A Data Science Library was developed in line with data science best practices.

The process is as follows:

- Business value, as identified by a Data Science Team customer (usually Trials and Business Team), was captured in a feature on Target Process. This feature was linked to a deliverable in Target Process
    - User Stories capture the customer requirements from this feature, and detail the acceptance criteria for completion
- Once a feature/user story was complete, it was marked as closed if:
    - The objectives of the feature had been completed
    - A corresponding notebook (if applicable) had been merged into the code base, with full documentation to be runnable by any Data Science Team member. This notebook was manually tested by the Data Science Team member responsible for the feature/user story
    - Corresponding source code had been merged into the code base, with full documentation in a consistent format and unit tests written if appropriate.

- Integration tests were written if the piece of code is expected to be run regularly and chain together many key dependencies of the library
- When core milestones/objectives are hit, the source code library received version upgrades, refreshing accompanying documentation pages on Confluence as appropriate
- For all bugs reported, these items were opened and tracked on Target Process, and marked as closed when the source code and documentation was updated and merged into the central code library.

When code is merged into the centralised, version-controlled library, it required a "code review" from another Data Science Team member.

Where the Data Science team was working with a data source/ dataset for the first time, it was standard practice to perform a "data discovery" on the data. This documents relevant patterns/findings in the data as a data quality checking exercise, and these outputs were communicated to relevant stakeholders. When required, other teams were re-engaged to refine the data ingestion or data curation process.

6.1.2.3 WS2 Depot Charge Points

Quality Assurance within the FAT site and the depots covers the following three distinct stages, the first two of which are further discussed in Section 4 of this document:

- **Installation and commissioning** – this was a discrete activity that occurred once and over a defined period. During this period, CP and CPC equipment is installed and tested in isolation (equivalent to unit test) by the electrical contractor. This activity ensures the equipment is functional and has been installed in accordance with the design.
- **Integration** – this was a discrete activity that occurred over a defined period. During this period the commissioned on-site equipment was integrated with remote (i.e. back office) systems connected via a wide area network (WAN). This activity constitutes operational readiness testing and ensured the charging *system* was functional.
- **Operation** – this was a continuous activity following the decision to move the charging system from readiness to in-service. During this activity quality assurance was via execution of procedures and processes governing the operation of the charging system. These included an element of data analysis to monitor the system for functional degradation and availability. During this period there was the introduction of new functionality, and functional and non-functional fixes. These were deployed by in-service update procedures to assure operational quality. The operational phase may continue beyond the end of the project.

6.2 Portfolio Level

The QA manager is responsible for the User Acceptance Testing process, including full end-to-end system testing and development of failure case plans.

6.2.1 User Acceptance Testing (UAT)

User Acceptance Testing provides an opportunity to get confidence that the entire end-to-end system (the IT capability, physical hardware, business processes and 'actors' which provide the end-to-end capability which allows the scope of Optimise Prime to be delivered) functions as expected. This is relevant both to the WS2 Depot (Royal Mail) solution and to elements of the WS1 Return-to-Home (Centrica) capability where this is delivered by the project team.

The UAT prerequisites were:

- Any user-story and feature-level testing has already been completed by the relevant application development and/or data analysis teams
- Integration/system testing has already been completed
- The FAT site has passed its sign-off checklist
- All physical infrastructure (CPs, CPCs, ethernet cabling, etc.) was installed in relevant test/pilot sites
- EVs were available
- Drivers were trained in using their electric vehicles, and CPs
- RFID authentication system had been setup, with RFID fobs allocated to depots and respective vehicles

6.2.1.1 Test cycle types

Test cycles help ensure that the breadth of scenarios are tested, maximising the chance of the overall system behaving as expected in a variety of scenarios:

Table 15 – Test cycle types

Cycle Type	Description
Normal	These tests demonstrate that the entire system, processes and people operate as expected, under planned operation
Exception	These tests demonstrate that the entire system, processes and people are still able to operate when different scenarios are explored, e.g. van in servicing
Error	These tests demonstrate that the system can safely navigate catastrophic system failures, minimising any further damage, and allowing business to continue operating

6.2.1.2 Actors

As well as the IT capability and processes being tested in UAT, various ‘Actors’ had roles, as they interacted with the overall system. They may have a direct active role in the Optimise Prime programme, or work within one of the Fleets, and so Optimise Prime has an impact on their BAU role as shown in Table 16.

Table 16 – Actors

Actor	Description
Driver	An individual who drives an EV within one of the in-scope fleets
Fleet/Depot Manager	An individual who requires oversight of the EV charging at one/more sites and/or covering multiple vehicles
DNO Flexibility Team	The DNO team responsible for providing flexibility options to the geographies in-scope for Optimise Prime
DNO Planning Team	The DNO team responsible for supporting 'Connection Surgeries' with depot-based fleet teams
CPC Support Team	The team who is responsible for the operations and maintenance of any CPCs
CP Support Team	The team who is responsible for the operations and maintenance of any CPs
Load monitoring team	The team who is responsible for the operations of the Power Radar equipment in each depot (not available at the FAT)

Actor	Description
UK Power Networks monitoring	The team who is responsible for the operations of the UK Power Networks load monitoring equipment in each depot or substation (not available at the FAT)

6.2.1.3 UAT Environments

Often, before a system goes live, the production environment (including the real devices that will be used) is used for UAT. This has the advantage that the environment that is being tested is exactly the same as the 'live' environment once the system begins operations. However, due to operational fleets being impacted (Royal Mail and Centrica) the project was faced with some restrictions, so as to avoid the possibility of interruption to operations. It was therefore planned that two environments would be set up in order to enable UAT without interrupting business operations:

- **FAT Site** – a Hitachi Capital site, in Trowbridge (N.B. this site features the systems installed at Royal Mail depots but does not have Royal Mail or Centrica vehicles)
- **Royal Mail Pilot Site** – a site with a 'ringfenced' number of vehicles and CPs used to conduct testing.

Running tests of systems and functionality at these sites was essential in ensuring that the Hitachi and Royal Mail were sufficiently confident in the reliability of the solution.

6.3 Acceptance Control

6.3.1 Acceptance Criteria

The acceptance criteria for all systems was that they did not have any unresolved critical or major issues.

Within Trials Management, Experiment Executions were accepted as completed if the results recorded met the Success Criteria.

6.3.2 Problem Reporting and Resolution

All defects and bugs identified through testing were assigned a rating:

- Cosmetic (least serious)
- Minor
- Major
- Critical (most serious)

The defect or bug were communicated back to the system lead for remedying, via the Target Process bug recording functionality.

6.3.3 Sign-off Process

Formal sign off of acceptance was required for final delivery of all system components.

6.3.4 Documentation

The documentation that describes and supports the Optimise Prime software, software development process, data engineering process and data analysis was created and will be updated periodically throughout the development cycle.

The following QA artefacts are used to document system quality:

- **Test Ready Report:** These reports were a pre-requisite for any run of a Test Plan. They entail formal sign off from each QA lead that all software and hardware is in place and that the Test Plan can be run.
- **Test Plan:** A set of Test Cases were created to test specific functionality and for repeating testing activities. For example, testing a feature or Experiment Execution. They were recorded in Target Process.
- **Test Case:** A set of test steps used to test a specific piece of functionality (e.g. a user story). Test Cases were recorded in Target Process and can be part of multiple Test Plans and executed multiple times.
- **Test Result**: The outcome of a run of a Test Case or Test Plan (i.e. Pass or Fail), was recorded in Target Process. Any bugs identified through the test process were recorded in Target Process.

7 Status of trial executions

7.1 Trial progress

The project's trial period has now begun – WS3 trials began in August 2020 while WS1 and 2 began on 1 July 2021 – all trials will run for a minimum of one year in order to capture seasonal variations within the dataset. The WS1 and 2 trials were delayed by 12 months from the original project plan in order to allow sufficient time for the partner fleets to acquire sufficient vehicles. All of the fleets have now met the minimum number of vehicles required for statistical significance (300 for WS1 and 200 for each of WS2 and WS3) and data is now being captured from over 3,000 EVs across the three trials.

Prior to the trial period, the project team has been running a series of pre-trial experiments on the available data in order to create baselines and perform analysis that will help further shape the trials executions. 48 executions of pre-trial experiments had been launched prior to the start of the trial period, covering all three workstreams. The outcomes from the pre-trial and initial trial activities will be reported in Deliverable D4.

Business modelling activities are also ongoing, including the execution of a series of surveys with drivers, considering behavioural impacts on the EV transition. This work is continuing and will be reported in Deliverable D5.

7.2 Trial locations update

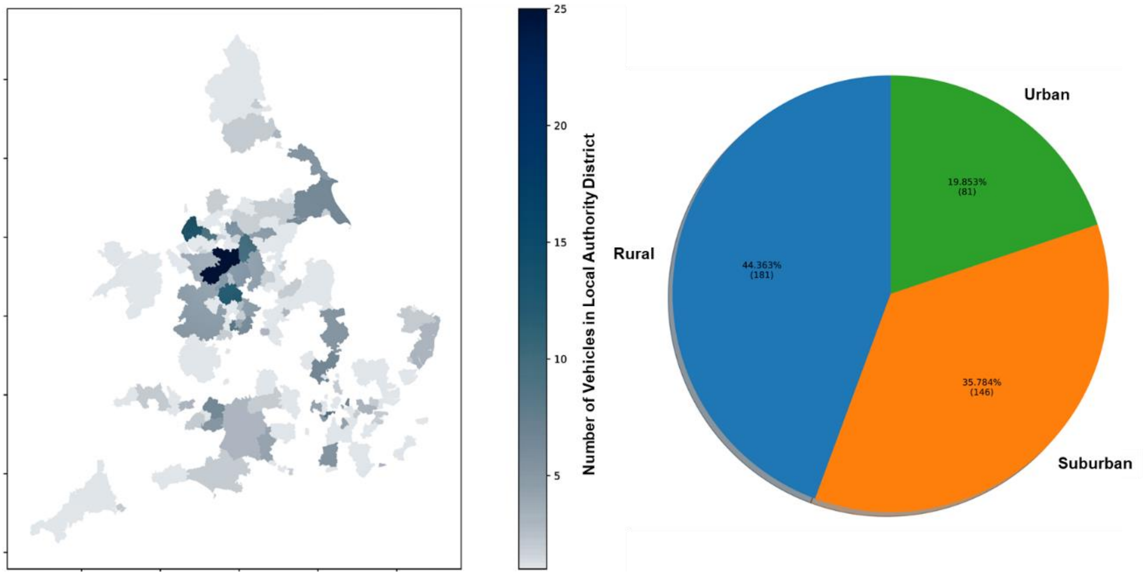
Technology and vehicles are being tested in a range of locations across the three trials, with varying approaches taken to site selection, depending on the specific requirements of each use case and the locations of the partner fleets. The project has now met the minimum requirement for the number of vehicles in each trial. However, the number of vehicles in the trials is expected to continue to increase, especially in WS1. The section below explains the locations of vehicles within the trials.

7.2.1 Home trials

The location of the Home trials is defined by where the drivers of the 'return-to-home' fleet vehicles live. Therefore, Optimise Prime has limited control over the locations where home trials will take place. There is also some risk of drivers changing locations as they move to a new house or change jobs. Due to the make-up of the British Gas fleet, it has been agreed to expand the area where data will be collected to the whole of the UK. Charging infrastructure will be installed at the homes of drivers of 'return-to-home' fleet vehicles wherever this is possible (there will be some EV drivers within the British Gas fleet who use public infrastructure, as they do not have off-street parking, so will not be able to take part in flexibility trials). The trial will capture data regarding the location of charge events in order to allow participation in demand response services and identify any issues from clustering. The diagram in Figure 27 shows a recent analysis of the location of British Gas EV drivers across England and Wales – the current sample shows that urban (19.9%), suburban (35.8%) and rural (44.4%)) locations are represented in the project, although with a slightly smaller proportion of urban drivers than the wider fleet (including ICE vehicles), likely due to the lack of off-street parking available in these areas.

At the time of writing there were over 390 British Gas EVs on the road across the UK – this is expected to reach a total of 1,000, with over 270 in the UK Power Networks and SSEN areas during the trial period.

Figure 27 – British Gas EV driver home locations by local authority in England and Wales (left), and breakdown by area type (right)



7.2.2 Depot trials

Nine EV-enabled Royal Mail sites are taking part in the trials. These locations have been chosen in order to balance potential risk and cost to Royal Mail with the learning opportunities and benefits that a particular site may give the project. This is an increase by two since the last deliverable – achieved by implementing an 'Over-the-Air' solution to control charging at two existing EV depots (Camden and Victoria/South Lambeth) without the need for additional on-site hardware and cabling (other than site load monitoring).

In October 2019, Royal Mail made the decision to delay its original electrification plans, because suitable vehicles could not be secured within their planned budget and changes to London's congestion charge, announced in December 2018, had impacted upon TCO (total cost of ownership) calculations, where EVs would be subject to the congestion charge from 2025. As a result of this, the originally planned second phase of depots and vehicles will not be implemented as part of the project, creating a shortfall against the originally planned 1,000 EVs for WS2.

Since this time, Royal Mail has made some additional investment in a small number of EVs to be added to the existing Optimise Prime depots (making use of existing infrastructure), and vehicles at the two additional depots have been added to the trials. As a result over 300 Royal Mail vans will now take part in Optimise Prime. As the locations are depots serving urban and suburban areas only, the project will compare ICE vehicle data from Royal Mail depots with more rural routes in order to observe any variations in shift and driving patterns that may impact on the project's modelling.

Table 17 shows the sites taking part in the WS2 Depot trials.

Table 17 – WS2 depot locations

Depot	Network	Number of EVs in use	Number of charge sockets installed
Islington	LPN	24	24
Whitechapel	LPN	32	33
Dartford	LPN	28	22
West London Premier Park	LPN	49	51
Mount Pleasant	LPN	122	87
Bexleyheath	LPN	12	6
Orpington	SPN	12	6
Camden	LPN	12	6
Victoria	LPN	12	6
Total		**303**	**241**

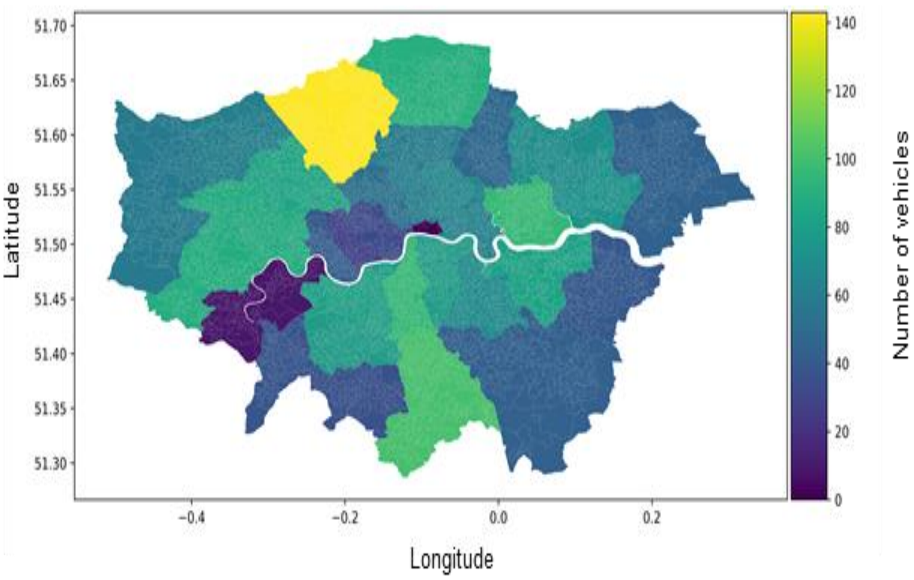
Note that the exact number of EVs at each site may continue to be subject to change in order to meet Royal Mail's operational requirements and as Royal Mail continue to implement their EV fleet expansion.

7.2.3 Mixed trials

The mixed trials do not involve the deployment of physical infrastructure at specific sites. Uber are providing the project with data from their PH EVs operating within the Greater London area. This data includes the geographical location of each vehicle when it changes status on the Uber app – for example when the driver comes online, when a trip is accepted, starts and ends. Over 1,500 EVs are now on the road as part of the trials.

As explained in Section 4, the project does not have full details of the home locations of drivers, but has modelled their likely locations based on journey data, as illustrated in Figure 28. Initial analysis has considered the split between drivers who charge in gaps during their shift (occurring in around 15-20% of driver shifts) and the remainder of drivers who charge off shift – either at or close to home, or on the way to a more central area to begin a shift.

Figure 28 – Estimated driver home location, by London borough, based on trip data



8 Conclusions & next steps

8.1 Conclusions

This report forms the key evidence for the third Optimise Prime deliverable. The project has successfully delivered on the requirements of deliverable D3 and this report provides a comprehensive overview of the lessons learned in the installation, commissioning and testing of the systems that are supporting the Optimise Prime trials. While the development of systems is now largely complete, there will likely continue to be some further development of systems based on learnings from the trials – where this happens any learnings will be reported in future deliverables.

This report should prove valuable to any DNO considering how to plan for the future growth of commercial EVs. The trial methodology may also prove useful to DNOs planning to implement similar innovation projects in the future. Vehicle fleet operators planning their transition to EVs should also find elements of this deliverable valuable, especially the lessons learnt from implementing smart control of depot fleets.

This report provided further detail on the applications and other solutions that the Optimise Prime solution is implementing in order to deliver its three trials. Particular focus is given to the challenges that the project has faced during the installation, commissioning and testing phases of the project.

Optimise Prime has uncovered a range of learnings through this work, covering a diverse range of issues, including the installation of equipment at homes and depots, interfacing multiple independent systems to provide smart charging control, developing a planning tool for depots, analysing charging based on trip data, implementing profiled connections and testing flexibility services. These learnings, and the work the project has done to overcome the related challenges, have been detailed throughout this report.

A significant challenge throughout the project has been populating the trials with sufficient commercial EVs to make each workstream statistically significant. This report sets out how, despite limited supply in the developing market for commercial EVs, the project partners have now met the minimum required vehicle volumes and details the locations where the trial vehicles will be based.

As mentioned in previous deliverables, the design of the Optimise Prime trials builds on learnings from several other Ofgem funded innovation projects and this deliverable report ensures future Innovation projects can build on the learning from Optimise Prime.

Following testing, the project solutions are now substantially complete, and this has allowed the WS1, WS2 and WS3 trials to begin on 1 July 2021. The project development teams are now transitioning to supporting activities and the data analysis activities are ramping up as more data is captured. The next deliverable, D4 will capture the initial insights from the trial activities.

For further questions on the evidence provided in this report, or more general questions about the project, please contact Optimise Prime team at: communications@optimise-prime.com or visit the project website www.optimise-prime.com.

8.2 Next steps: Open items and future activities

Following the installation and testing of trial systems work is proceeding to:

- Run the three Optimise Prime trials, which have now begun and will continue for 12 months. Throughout the trials data will be collected and analysed from vehicles and charging infrastructure
- Complete the final work on the flexibility solutions to enable the testing of all three flexibility products
- Utilise the test site to trial a variety of charging regimes before rolling them out to live depots
- Continue to capture and analyse data from the vehicles and chargers in order to refine plans for the trial and business model
- Launch the web-based site planning tool
- Continue to engage with stakeholders through communications and events
- Publish the initial findings from the trials in Deliverable D4 and the initials findings regarding business models in Deliverable D5.

9 Appendices

9.1 Appendix – Stage 3 Commissioning Tests at FAT site

The following table shows a set of example tests and results from Stage 3 Commissioning testing.

Test ID	Test name	Test Procedure	Expected Result	Test Result
1	Alfen single socket limitation and relaxation	Send the following current limit request from the USP to socket 1 of the CP 32A -> 16A -> 8A -> 0A -> 18A -> 10A -> 32A	1. Current limit request confirmed in USP and iHost 2. CP charges EV in response to current limit	PASS 1. Current limit request confirmed in USP and iHost 2. CP charges EV in response to current limit
2	Alfen dual socket limitation and relaxation – socket 1	Send the following current limit request from the USP to socket 1 of the CP 32A -> 16A -> 8A -> 0A -> 18A -> 10A -> 32A	1. Current limit request confirmed in USP and iHost 2. CP charges EV in response to current limit	PASS 1. Current limit request confirmed in USP and iHost 2. CP charges EV in response to current limit
3	Alfen dual socket limitation and relaxation – socket 2	Send the following current limit request from the USP to socket 2 of the CP 32A -> 10A -> 32A	1. Current limit request confirmed in USP and iHost 2. CP charges EV in response to current limit	PASS Current limit tests reduced because of time constraint 1. Current limit request confirmed in USP and iHost 2. CP charges EV in response to current limit
4	Alfen dual socket simultaneous limitation and relaxation – sockets 1 and 2	Send the following current limit request from the USP to both sockets of the CP 32A -> 16A -> 8A -> 0A -> 18A -> 10A -> 32A	1. Current limit request confirmed in USP and iHost 2. CP charges EV in response to current limit	PASS 1. Current limit request confirmed in USP and iHost 2. CP charges EV in response to current limit
5	eVolt dual socket limitation and relaxation – socket 1	Send the following current limit request from the USP to socket 1 of the CP 32A -> 16A -> 8A -> 18A -> 10A -> 32A	1. Current limit request confirmed in USP and iHost 2. CP charges EV in response to current limit	PASS 1. Current limit request confirmed in USP and iHost 2. CP charges EV in response to current limit
6	eVolt dual socket limitation and relaxation – socket 2	Send the following current limit request from the USP to socket 2 of the CP 32A -> 16A -> 8A -> 18A -> 10A -> 32A	1. Current limit request confirmed in USP and iHost 2. CP charges EV in response to current limit	PASS 1. Current limit request confirmed in USP and iHost 2. CP charges EV in response to current limit

9.2 Appendix – Acceptance Testing of the TOA solution at the Royal Mail Depots

The following tables detailed the tests carried out as part of the acceptance testing of the TOA solution and the result recorded at each of the nine depots.

9.2.1 TOA dashboard

ID	Test Case	Priority	Bex	Cam	Dar	Isl	Mou	Nin	Orp	Pre	Whi
TDB01	As a TOA dashboard user I can view all CPC > CP > CS hierarchies at the chosen depot.	L	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
TDB02	As a TOA dashboard user I can view the operational status of all CSs at the chosen depot.	L	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
TDB03	As a TOA dashboard user I can view the vehicle registration of all EVs plugged in at the chosen depot.	L	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
TDB04	As a TOA dashboard user I can view the current realpower consumption for all EVs charging at the chosen depot.	L	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
TDB05	As a TOA dashboard user I can view the setpoint for all EVs plugged in at the chosen depot.	L	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
TDB06	As a TOA dashboard user I can view the latest depot load at the chosen depot.	L	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
TDB07	As a TOA dashboard user I can view the grid connection limit and the buffer at the chosen depot.	L	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
TDB08	As a TOA dashboard user I can view the latest EV load (load being consumed by EVs) at the chosen depot.	L	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
TDB09	As a TOA dashboard user I can view the depot headroom at the chosen depot.	L	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
TDB10	As a TOA dashboard user I can view a current graph of demand (Building Load + EV Load), Headroom and Building Capacity at the chosen depot.	L	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
TDB11	As a TOA dashboard user I can view a 7 day historic graph of demand (Building Load + EV Load), Headroom and Building Capacity at the chosen depot.	L	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
TDB12	As a TOA dashboard user I can view a graph of average demand (Building Load + EV Load), Headroom and Building Capacity at the chosen depot.	L	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
TDB13	As a TOA dashboard user I can view a graph of future demand (Building Load + EV Load), Headroom and Building Capacity at the chosen depot.	L	Descoped								

9.2.2 Headroom calculation, setpoint calculation and sending

ID	Test Case	Priority	Bex	Cam	Dar	Isl	Mou	Nin	Orp	Pre	Whi
SET01	Given I am at the TOA backend When a new message is received in one of the sources: Depot Capacity, Panoramic Power, CP state or Depot latest Then (a) the depot_capacity_kw is calculated, multiplying the depot_capacity_kva by the power_factor [kw = kva x power factor] And (b) the building_load is calculated, dividing the power(W) by 1000 [Building Load (kW) = power(W)/1000] And (c) the ev_load is calculated through the sum of all realpower values [EV Load = ∑ realpower] And (d) I get the depot_buffer_kw And I Calculate Headroom a – b + c – d And if > 0 Then this is the final headroom	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
SET02	Given I am at the TOA backend When a new message is received in one of the sources: Depot Capacity, Panoramic Power, CP state or Depot latest Then (a) the depot_capacity_kw is calculated, multiplying the depot_capacity_kva by the power_factor [kw = kva x power factor] And (b) the building_load is calculated, dividing the power(W) by 1000 [Building Load (kW) = power(W)/1000] And (c) the ev_load is calculated through the sum of all realpower values [EV Load = ∑ realpower] And (d) I get the depot_buffer_kw And I Calculate Headroom a – b + c – d And if not > 0 Then 0 is the final headroom	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
SET03	Given I am at the TOA backend When a valid setpoint is sent to iHost And iHost replies within the expiry time defined in field <et> And iHost accepts the setpoint Then iHost responds through Kafka topic ihost.controlresponses And the field <rc> (result code) is received with value 0 (Accepted)	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

9.2.3 Profiled Connection management

ID	Test Case	Priority	Bex	Cam	Dar	Isl	Mou	Nin	Orp	Pre	Whi
PCM01	As a SysAdmin/FleetAdmin/ DepotAdmin within the TOA dashboard I can add a Profiled Connection.	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
PCM02	As a SysAdmin/FleetAdmin/ DepotAdmin within the TOA dashboard I can edit a Profiled Connection	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
PCM03	As a SysAdmin/FleetAdmin/ DepotAdmin within the TOA dashboard I can delete a Profiled Connection	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
PCM04	As a SysAdmin/FleetAdmin/ DepotAdmin within the TOA dashboard I can view a Profiled Connection graph	L	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
PCM05	As a SysAdmin/FleetAdmin/ DepotAdmin within the TOA dashboard I can duplicate a Profiled Connection.	L	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
PCM06	As a TOA dashboard user When a Profiled Connection is created for a depot Then TOA setpoints remain within the Profiled Connection times and power usage	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

9.2.4 Depot driver behaviour

ID	Test Case	Priority	Bex	Cam	Dar	Isl	Mou	Nin	Orp	Pre	Whi
DDB01	As a depot driver When I use a RFID card to authenticate a CS Then I can connect an EV to the CS And the EV to CS connection is communicated to TOA And the RFID tag is communicated to TOA	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
DDB02	As a depot driver When I use a RFID card to authenticate a CS And I connect an EV to the CS And charging begins Then the charging realpower is communicated to TOA	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
DDB03	As a depot driver When I use a RFID card to authenticate a CS And I connect an EV to the CS And I use the same RFID card to end the CS session And unplug the EV from the CS Then the available CS is communicated to TOA	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

ID	Test Case	Priority	Bex	Cam	Dar	Isl	Mou	Nin	Orp	Pre	Whi
DDB04	As a depot driver When I use a RFID card to authenticate a CS And I connect an EV to the CS And I use the same RFID card to end the CS session And leave the EV plugged into the CS Then the EV to CS connection is communicated to TOA	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
DDB05	As a depot driver When I use a RFID card to authenticate a CS And I connect an EV to the CS And unplug the EV from the CS Then the available CS is communicated to TOA	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
DDB06	As a depot driver When I use a RFID card to authenticate a CS And I connect an EV to the CS And unplug the EV from the CS And use the same RFID card to authenticate the CS again Then the EV to CS connection And the RFID tag is communicated to TOA	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
DDB07	As a depot driver When I use a RFID card to authenticate a CS And connect an EV to the CS And the EV reaches a full state of charge Then this is communicated to TOA	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
DDB08	As a depot driver When I don't use a RFID card to authenticate a CS And I connect an EV to the CS Then the preparing CS is communicated to TOA And charging cannot begin	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
DDB09	As a depot driver When I use a RFID card to authenticate a CS And I connect an EV to the CS And I use the same RFID card to authenticate another brand of CS Then I can connect an EV to the second CS And both EV to CS connections And two instances of the RFID tag are communicated to TOA	H	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
DDB10	As a depot driver When I use a RFID card to authenticate a CS And I use the same RFID card to authenticate another brand of CS Then I can connect an EV to each CS And both EV to CS connections And two instances of the RFID tag are communicated to TOA	H	Descoped								

ID	Test Case	Priority	Bex	Cam	Dar	Isl	Mou	Nin	Orp	Pre	Whi
DDB11	As a depot driver When I use a RFID card to authenticate a CS And I connect an EV to the CS And the first EV to CS connection is communicated to TOA And the RFID tag is communicated to TOA And I attempt to use the same RFID card to authenticate another CS of the same brand Then the second authentication fails	H	Descoped								

9.2.5 Exception Monitoring

ID	Test Procedure	Priority	Result
EXC01	Given I am at Grafana monitoring the last message received from Nortech for each Charge Socket When no Nortech message is received for 60 seconds Then the alert level changes to red And an alert is sent to dai-eng Slack channel	H	Pass
EXC02	Given I am at Grafana monitoring the last state of charge for each vehicle When no message from Mercedes Telematics is received for 3 minutes Then the alert level changes to amber	L	Descoped
EXC03	Given I am at Grafana monitoring the last state of charge for each vehicle When no message from Mercedes Telematics is received for 5 minutes Then the alert level changes to red And an alert is sent to dai-eng Slack channel	L	Pass
EXC04	Given I am at Grafana monitoring the last message received for each site When no message from Panoramic Power is received for 7 minutes Then the alert level changes to amber	H	Descoped
EXC05	Given I am at Grafana monitoring the last state of charge for each vehicle When no message from Panoramic Power is received for 10 minutes Then the alert level changes to red And an alert is sent to dai-eng Slack channel	H	Pass
EXC06	Given I am at Grafana monitoring the ingestions from Darksky When the ingestion has not run with success status Then the alert level changes to red And an alert is sent to dai-eng Slack channel	L	Pass
EXC07	Given I am at Grafana monitoring the ingestions from Nortech When the ingestion has not run with success status Then the alert level changes to red And an alert is sent to dai-eng Slack channel	H	Pass
EXC08	Given I am at Grafana monitoring the ingestions from Mercedes When the ingestion has not run with success status Then the alert level changes to red And an alert is sent to dai-eng Slack channel	M	Pass
EXC09	Given I am at Grafana monitoring the ingestions from Axodel When the ingestion has not run with success status Then the alert level changes to red And an alert is sent to dai-eng Slack channel	M	Pass

9.2.6 Bug Detail

The acceptance testing raised a number of bugs, which are detailed below. All critical bugs have been resolved.

Bug Id	Title	Severity	State
17044	TOA AT: Assets State Monitoring dashboard time and date formats	Enhancement	In Progress
17053	TOA AT: Assets State Monitoring dashboard Auth Time missing for some charge sockets	Small	Abandoned*
17060	TOA AT: Assets State Monitoring dashboard Auth Time value query	Small	In Progress
17062	TOA AT: Depot dashboard display of Depot Capacity, Building Load and Capacity Buffer	Normal	Done
17394	TOA AT: Assets State Monitoring dashboard showing EV registration for Available sockets	Enhancement	In Progress
17532	TOA AT: Some known EVs are not being optimised	Critical	Done
17534	TOA AT: Strange Realpower reading displayed in dashboard	Normal	Done
17538	TOA AT: Bexleyheath and Orpington charge points displaying old Status, Auth, Power and Setpoint times	Small	Abandoned*
17556	TOA AT: Display of Capacity, Latest Depot Load, Latest EV Load, Buffer values in Depot Dashboard on smaller screens	Enhancement	In Progress
17557	TOA AT: Depot Dashboard graph tool tip displays incorrect EV load value	Small	In Progress
17559	TOA AT: Profiled connection for a single date being stored with same start and end date and time	Normal	Abandoned*
17565	TOA AT: Interruption in depot dashboard reporting	Critical	Done
17673	TOA AT: Interruption in Premier Park setpoints between 14:25 and 15:05 on 23-06-2021	Critical	Done
17819	Swarco AT: whitechapelota.evc0010.sk1 showing as charging but not reporting realpower	Normal	Done

*Abandoned bugs were investigated and were found to be due to either circumstances unique to the trial or asset setup issues.

9.3 Appendix – Flexibility Product A Test Execution Results

ID	Test Case	Priority	Status	Comment
E2EPA001	Application to Register FSP is REJECTED	Low	Not Completed	This Test was not completed. Deemed Very Low Priority, as only FSPs in the Trials can apply, so they would not be rejected in reality.
E2EPA002	Application to Register FSP is ACCEPTED	High	Pass	SGS registered UUIDs for Victoria, Dartford and Premier Park
E2EPA003	Application to Register a further Flexibility Unit	Low	Not Completed	Requested the additional Registration of Bexleyheath as a FU, but SGS did not have the resource to do this at the time.

ID	Test Case	Priority	Status	Comment
E2EPA004	FSP receives Flexibility Requirements and decides NOT to submit a bid	Low	Not Completed	This is a Very Low Priority Test, and since nothing happens if we don't submit a bid, not really relevant.
E2EPA005	UK Power Networks rejects a bid submitted by the FSP, as the Tender does not cover the FSP FU Area.	Low	Not Completed	This is a Very Low Priority Test, and the Rejection of a Bid was covered in E2EPA006.
E2EPA006	UK Power Networks rejects the bid from the FSP, as the price offered in the Tender is not attractive to the FSP.	Low	Pass	UK Power Networks did reject bid based on the price submitted in the bid.
E2EPA007	Dispatch instructions are sent to the FSP via API. The power downturn is initiated, and ends when Flexibility period ends.	High	Failed	Failed due to lower than expected EV load thought to be as a result of a CSMS authentication outage, but Flexibility was initiated and completed, so now **Awaiting Settlement** results from UK Power Networks.
E2EPA008	Dispatch instructions are sent to the FSP via API. The power downturn is initiated and ends when the Runtime period of the Flexibility ends.	High	Awaiting Settlement	Test completed and observed in TOA. **Awaiting Settlement** results from UK Power Networks.
E2EPA009	Dispatch instructions are sent to the FSP via API. The power downturn is initiated. Before the end of the Flexibility Period, and the Run Period have completed, UK Power Networks send a Dispatch Instruction (via API) with a zero-power value to end the Flexibility downturn.	High	Failed	Failed - Bug raised, but Flexibility was initiated and completed, so now **Awaiting Settlement** results from UK Power Networks. The flexibility period started as expected but ended on receipt of the zero-value command, and not at the time in the API message.
E2EPA010	FSP sends an API request to UK Power Networks informing them of Unplanned System Unavailability, using the Firm Forward APIs Send Service Status value = false. Thus the Flexibility period cannot be initiated.	High	Descoped	Descoped : this test couldn't be completed as the manual schedule implemented on the ANM system doesn't take service status into account.
E2EPA011	Before the Strata Optimisation process runs, the integration is lost between Strata and TOA, and thus no Dispatch instructions can be sent to the FSP via API, and the Flexibility period cannot be initiated.	High	Not Tested	This was not tested, as the functionality had been proven as part of the integration testing.
E2EPA012	Dispatch instructions are sent to the FSP via API, but there is a Charging Point Infrastructure failure (e.g. a CPC controller failure results in Setpoints not being set).	Medium	Awaiting Settlement	This test could not be tested directly due to being unable to force a Charging Point issue in a Production Depot. However, the outage that effected tests E2EPA007 and E2EPA008 effectively tested this scenario successfully.
E2EPA013	Dispatch instructions are sent to the FSP via API, but there is an operational issue at the FSP, meaning no electric vehicles are available for charging during the downturn.	Medium	Awaiting Settlement	This test could not be tested directly due to being unable to force a Charging Point issue in a Production Depot. However, the outage that effected tests E2EPA007 and E2EPA008 effectively tested this scenario successfully.

ID	Test Case	Priority	Status	Comment
E2EPA016	Dispatch instructions are sent to the FSP via API. The power downturn is initiated, and ends when Flexibility period ends.	High	Failed	Failed – impacted by same bug as E2EPA009, so now **Awaiting Settlement** results from UK Power Networks.
E2EPA017	The Dispatch instruction is sent the FSP via API outside of the Flexibility window agreed. The power downturn should not be initiated.	High	Awaiting Settlement	Test completed and no turndown observed. Awaiting the settlement data from UK Power Networks.