AI-informed Holistic Electric Vehicles Integration Approaches for Distribution Grids

D9.3

Installation, Commissioning and Integration, Western

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EXECUTIVE SUMMARY

The Western Europe demonstrator deliverable describes its installation and commissioning work and system integration testing for the deployment of electric vehicle charging infrastructure in public, semi-public, and private residential areas which were tested at multiple real-world sites. The current work uses system design together with use case definition which was established in previous project phases to create a physical system developed from its original conceptual design. The demonstrator system consists of multiple deployment sites which appear throughout Funchal and Lisbon that include public charging stations, a tourist port, semi-private parking areas and a residential building with multiple units that use photovoltaic (PV) solar energy systems.

The implemented infrastructure provides various EV charging solutions which include standard Electric Vehicle Supply Equipment's (EVSEs), Open Charge Point Protocol (OCPP) compatible devices and a distributed metering system that delivers precise power monitoring throughout the entire system. The project team makes interoperability, system integration, and communication interface validation their focus because these elements should enable systems to work together in a synchronized manner. The commissioning process verified proper functionality of all installed components through different verifications which included electrical validation, communication system installation and operational assessment. The developed systems create complete operational testing environment which include all necessary instruments to execute advanced research on coordinated electric vehicle charging and energy management systems.

The present document serves as the technical basis which will support future operation and monitoring and assessment activities for the demonstrator system. The infrastructure which has been installed permits testing of electric vehicle integration under authentic operational circumstances.

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ACRONYMS

CPO	Charging Point Operator
CSMS	Charging Station Management System
DER	Distributed Energy Resources
DSO	Distribution System Operator
EMS	Energy Management System
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
MQTT	Message Queuing Telemetry Transport
OCA	Open Charge Alliance
OCHP	Open Clearing House Protocol
OCPP	Open Charge Point Protocol
OCPI	Open Charge Point Interface
OICP	Open InterCharge Protocol
Open ADR	Open Automated Demand Response
OSCP	Open Smart Charging Protocol
PV	Photovoltaic
RES	Renewable Energy Sources
SAT	Site Acceptance Tests
TSO	Transmission System Operator
TIR	Technical Information Request
V1G	Controlled Unidirectional Smart Charging
V2B	Vehicle-to-Building
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home
V2L	Vehicle-to-Load
V2X	Vehicle-to-Everything
WED	Western Europe Demonstrator

1. INTRODUCTION

This deliverable presents the installation, commissioning, and integration of the infrastructure deployed in the Western Europe Demonstrator (WED), one of the key three demonstrators of the AHEAD project, supporting the validation of the defined use cases (UCs) [1]. The work covers the deployment of electric vehicle supply equipment (EVSE) across different operational environments, enabling the assessment of charging strategies, grid interaction, and flexibility services under real conditions. The WED will install and operate EVSEs at two demonstration sites which are in Funchal and Lisbon to provide charging services at residential areas and public spaces and private parking lots. The test sites will support multiple use cases which include smart charging and V2X operation and flexibility services and grid planning activities under actual operational limitations of various system conditions.

The Funchal area will establish charging stations which will provide power to EVs while supporting two planning goals that require EVSEs to be built in port facilities and urban areas. The Lisbon project focuses on electric vehicle charging needs at large parking facilities while developing ways to manage local energy needs and PV systems and flexibility services with a trustworthy and safe system.

1.1. Scope and Objectives

The WED digital platform operates integrated infrastructure to collect data which enables stakeholders to access different application functions through data aggregation and model building. The system enables various parties to work together on charging management through their active role and charging station operators and EV drivers and distribution system operators (DSOs).

The main objectives of this deliverable are:

- To deploy and integrate EV charging infrastructure across multiple environments, ensuring coverage of the defined demonstration scenarios.
- To ensure interoperability between EVSEs, communication platforms, and control systems, supporting coordinated operation across stakeholders.
- To support the integration of EV charging within local energy systems, including interaction with distributed energy resources (DERs) such as PV generation.
- To enable participation in flexibility mechanisms and assess their impact on grid operation and planning.

- To provide a validated and scalable infrastructure baseline for the demonstration of AI-based tools and services developed within the project.

The outcomes of this deliverable establish the technical and operational conditions required for the large-scale validation of coordinated EV charging solutions in heterogeneous environments.

1.2. Document Structure

The deliverable consists of four main sections which each focus on a different aspect of the WED demonstrator. The first section of the document presents its introduction which establishes the document's goals and boundaries while showing how its content connects to other project deliverables and work packages. The second section of the document focus on the installation and commissioning work which took place at the WED sites, by describing how charging infrastructure was installed in Funchal through public charging networks, the touristic port area, a private multi-unit garage and the semi-public parking lot installation which occurred in Lisbon. The WED operates through functional architecture which includes its control platform together with its main systems and its interoperability systems which enable different systems to work together, which is described in Section 3. The implementation and integration work results in Main conclusions and recommendations which Section 4 of the document presents.

1.3. Relation to other Deliverables and Work packages

The present deliverable connects multiple tasks because it enables seamless progression through several stages from design to deployment to operation to evaluation of the WED demonstrator. The deployment activities described in this deliverable are aligned with *T2.3 – Development of smart and bidirectional charger for electric vehicles*, which focuses on the development of smart and bi-directional EV charging technologies, providing key hardware components validated in laboratory conditions that also will be validated in the Lisbon pilot. The WED demonstrator establishes its foundation through *T9.1 – Detailed Specification of the Demonstration Use Cases*. The Funchal port area digital twin project receives support from T9.2 – *Development of a Digital Twin of the Maritime – Tourism area of the Funchal Port*. The installed infrastructure and integrated systems described in this deliverable constitute the basis for *T9.4 – Operation and Monitoring*, which uses operational data to monitor system performance and test various use cases. The results of this research directly support *T9.5 – Analysis of Results,* which evaluates results and KPIs and T9.6 – Lessons Learned and Scalability, which assesses lessons learned and scalability aspects for solution replication and large-scale implementation.

2. INSTALLATION AND COMMISSIONING

This section presents the installation, commissioning, and integration activities which took place in the WED demonstrator after the design and planning phase which *T9.1 – Detailed Specification of the Demonstration Use Cases* defined [2]. The WED demonstrator architecture and infrastructure requirements and UCs and integration strategies for the four pilot sites in Funchal and Lisbon. The study required the specification of EVSE technologies and communication protocols which included Open Charge Point Protocol (OCPP) [3] and Message Queuing Telemetry Transport (MQTT), and the data flows and system architecture needed to implement coordinated charging and flexibility services. The WED demonstrator development status in D9.1 [2] shows that the system development work has advanced to infrastructure planning and site selection and partial deployment activities. The WED demonstrator started by building physical infrastructure at the Lisbon semi-public parking lot while installing EVSE units at the Funchal public charging network.

The section describes how organizations deploy their EVSE systems which work with their existing infrastructure. Organizations will test their systems through various use cases which will operate at full capacity.

2.1. Funchal: Public Charging Network

2.1.1. Initial setup

The demonstration area covers the city of Funchal, encompassing the public electric vehicle charging infrastructure, with a particular focus on assets managed by the Funchal City Hall (CMF) and the EEM Group. At the time of writing, the city includes a total of 49 public charging stations, corresponding to 98 charging sockets. Of these, 19 stations (38 sockets) are managed by CMF and are located either on-street or within municipal parking facilities. Additionally, two on-street locations, comprising 5 sockets, are operated by EMACOM. The remaining 27 charging stations are owned and operated by other entities and are distributed across various locations, including fuel stations and private or semi-public parking areas.

2.1.2. Pre-installation activities

As part of the AHEAD demonstration activities, six additional EVSEs will be integrated into the public charging network. This includes the deployment of one bidirectional (V2G) charger rated at 11 kW in a public parking facility, two single-connector V1G chargers rated at 22 kW, and two double-connector V1G chargers rated at 22 kW.

It should be noted that earlier project documentation (D9.1) [2] considered single-connector chargers operating at 7.4 kW. This specification has since been updated to 22 kW to better reflect the requirements of public, on-street charging scenarios, where higher power levels are preferable to reduce charging times, improve user turnover, and align with the capabilities of three-phase infrastructure available at the selected locations.

In addition, two fast V1G chargers (50 kW and 60 kW) already installed in the network will be integrated into the demonstration framework. Furthermore, subject to feasibility, a smart meter will be installed at the main distribution board of the selected public parking facility to enable monitoring of the overall building-level electrical demand.

2.1.2.1. Selection of the four street charging locations

- **Location 1 – Rua da Achada:** Location 1 is intended for the installation of a 22 kW AC charging station (Alfen EVE Single Pro) in a perpendicular on-street parking space. As there is no existing infrastructure (from a previously installed charger) to be reused, the intervention will require installing a new auxiliary distribution cabinet, which must be embedded (recessed) into the existing stone wall adjacent to the current cabinet. Civil works are planned to open channels in the wall, ensuring the concealed routing of the power cables from the new distribution board to the charger, which will be mounted at the upper level (at road elevation), at the end of the parking area, approximately 13 meters from the cabinet. The works will be completed by installing metal bollards to protect the charger, painting horizontal road markings on the pavement, and installing vertical signage on a dedicated post to ensure exclusive regulation of the space. Figure 1 and Figure 2 provide further details about the site and the proposed installation.

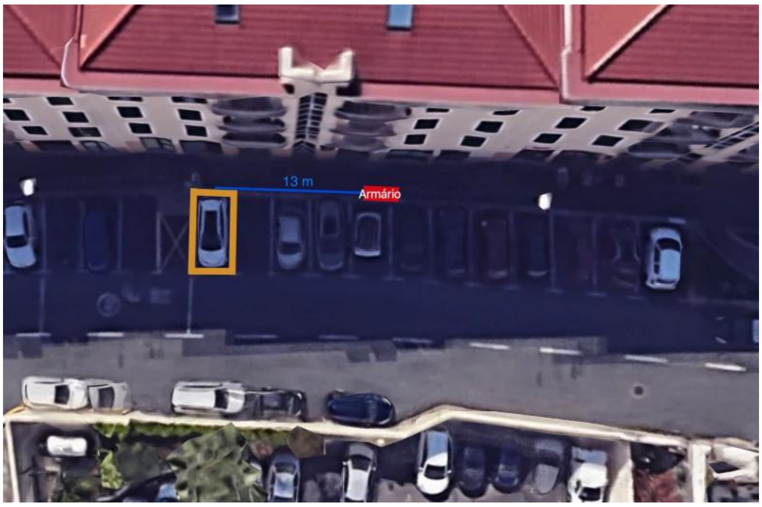


Figure 1– Aerial view of the parking area to be electrified and the estimated cable routing.

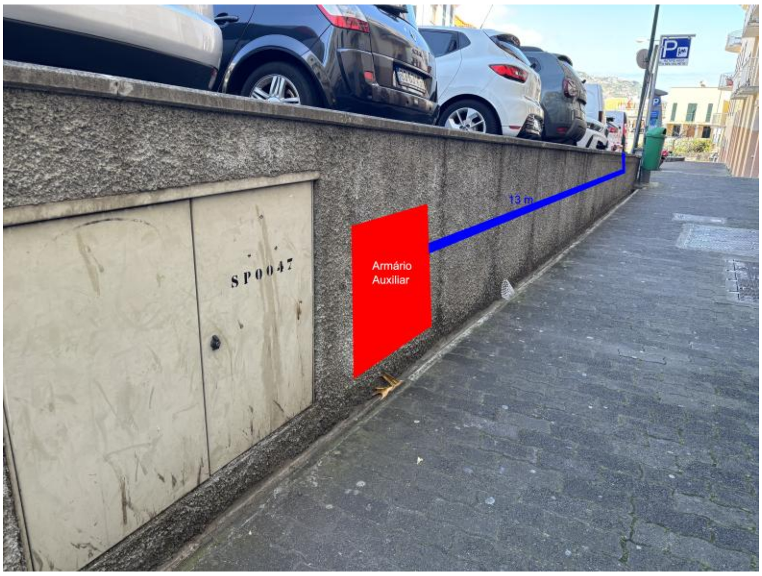


Figure 2 – Location of the auxiliary cabinet to be embedded in the wall and the corresponding connection route.

- **Location 2 – Rua dos Ferreiros:** This location is intended for the installation of a 22 kW AC charging station (Alfen EVE Single Pro) in a perpendicular on-street parking space. The intervention will require the Contractor to assess the reuse of the existing charging station cabinet at the site for the integration of new electrical protections and metering, including, in the proposal, an auxiliary cabinet in case the available space is insufficient. Additionally, civil works are planned for the trench opening and reinstatement in the cobblestone pavement to enable the routing of power cables to the equipment pedestal. The works will be completed by installing metal bollards to protect the charger. Further details of this location are presented in Figure 3.

Figure 3 – Aerial view of Location 2 with identification of the cable routing.

- **Location 3 – Rua do Vale da Ajuda:** Location 3 is intended for the installation of a dual 22 kW AC charging station (Alfen EVE Double Pro) in an on-street parking space. As this is a completely new installation, the intervention will require installing a new auxiliary distribution cabinet in the unpaved area designated as a “green space,” adjacent to the existing main electrical cabinet. Civil works will take place on regular pavement, without structural obstacles or limiting elevation differences, consisting essentially of trench excavation for routing power cables from the cabinet to the flat area where the charger will be installed. The works will be completed with the installation of metal bollards to protect the equipment from impacts. Further details of this location are presented in Figures 4 and 5.

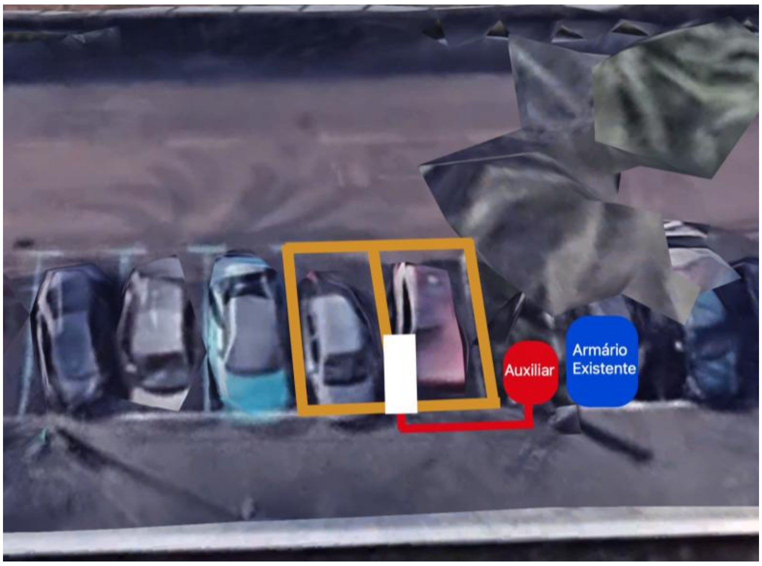


Figure 4 – Aerial view of the layout of the parking spaces, charger, and distribution cabinets.

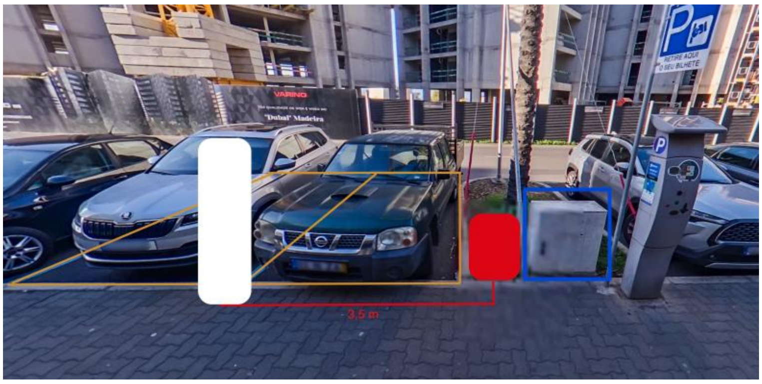


Figure 5 – Street-level view highlighting a possible cable routing and its approximate distance.

- **Ponto 4 – Rua do Gorgulho:** Location 4 is intended for the installation of a dual 22 kW AC charging station (Alfen EVE Double Pro) in an on-street parking space. The site already has a dual charger, and its corresponding protection and metering cabinet previously installed. The intervention will require an assessment of the existing electrical infrastructure, with the installation of a new auxiliary cabinet in the adjacent unpaved area (green space) being foreseen. Civil works are characterized by the absence of structural constraints, with trenching for cable routing occurring predominantly in soil areas, thereby minimizing intervention on the road pavement. The works will be completed with the installation of the equipment on a dedicated pedestal and the placement of metal bollards to protect the new installation. Further details of this location are presented in Figures 6 and 7.

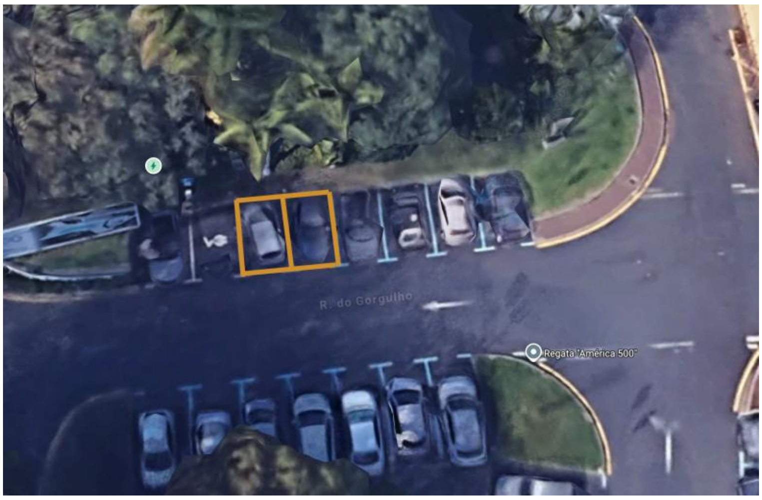


Figure 6 – Aerial view of Location 4, identifying the two parking spaces to be electrified.

Figure 7 – View of the site highlighting the existing electrical infrastructure.

2.1.2.2. Public parking lot technical assessment

A technical assessment of the site was conducted through an on-site inspection performed by EEM to evaluate the capacity of the existing electrical infrastructure to accommodate an additional 11 kW bidirectional (V2G-enabled) EV charger. The assessment confirmed that the installation is suitable for the proposed expansion, as the infrastructure had previously been upgraded to support two 22 kW chargers integrated within the Mobi.E network and owned by CMF.

The new charger will be installed on the fourth floor of the parking facility, serving two designated parking spaces (Figure 8). The main electrical distribution board is located on the ground floor (floor zero), requiring approximately 25 meters of power cabling between the supply point and the charging unit. The cable routing will follow the same pathway as a previously installed EVSE located on the same floor and position, ensuring compliance with applicable safety and technical standards while minimizing installation complexity and civil intervention.

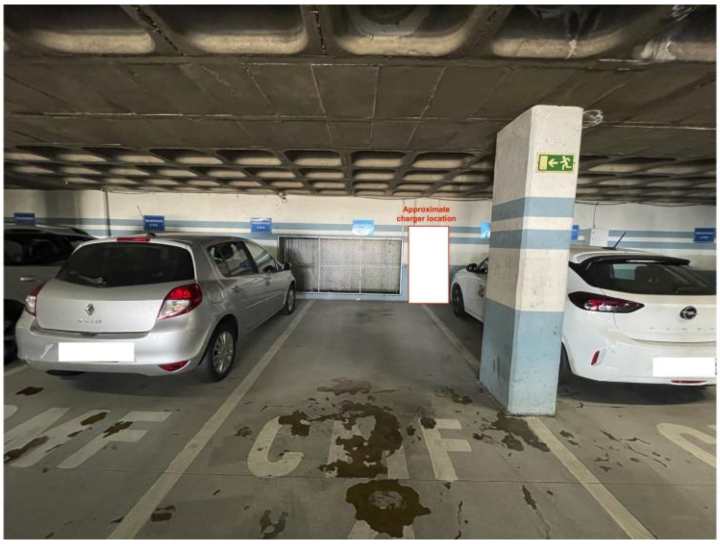


Figure 8 – Approximate location of the V2G charger to install, enabling its usage by either the EV to the left or to the right.

To support the technical assessment, an analysis of the parking facility's electrical load profile was conducted for a representative period (August 2025), as shown in Figure 9. The results indicate a relatively stable base load of approximately 9–11 kW, with intermittent peaks reaching up to approximately 25–27 kW. These peak events are consistent with the operation of existing EV charging infrastructure at the site, namely a three-phase *Wallbox* with nominal power in the range of 22 kW. The short duration and intermittent nature of these peaks indicate that the installation is already capable of accommodating high-power charging events without sustained stress on the system.

Overall, with a peak power capacity of 63 kVA for the entire parking lot, the load profile confirms that sufficient capacity is available to integrate an additional 11 kW bidirectional charger without requiring reinforcement of the existing connection under typical operating conditions. Furthermore, the observed demand patterns demonstrate that the site is inherently suitable for implementing smart, bidirectional charging strategies, enabling load shifting and the provision of flexibility services while maintaining system reliability and supporting the objectives of the AHEAD project.

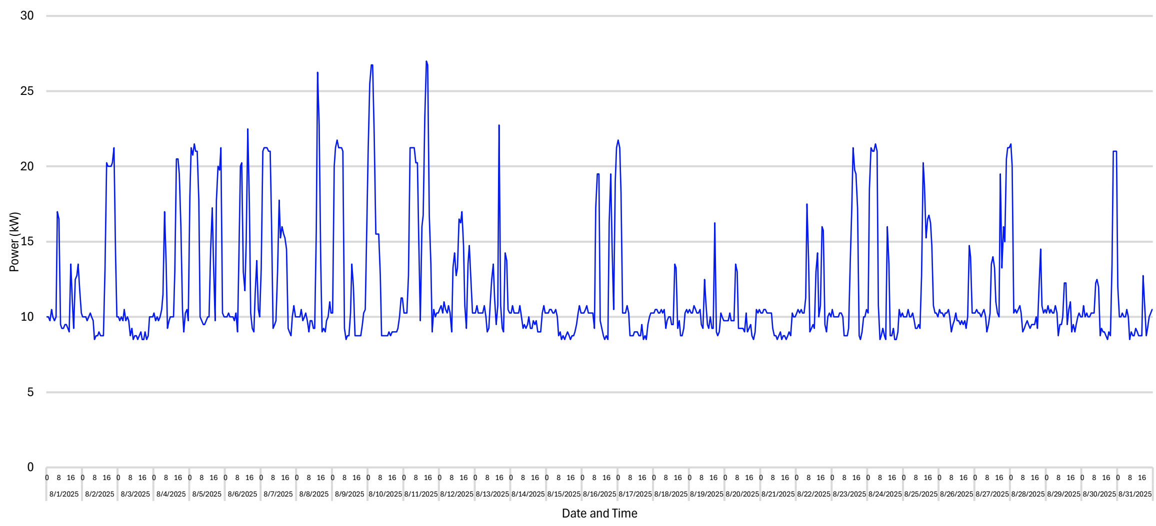


Figure 9 – Parking lot load profile for August 2025.

2.1.3. Procurement activities

2.1.3.1. EV charging equipment procurement

The five EV chargers to be installed at the selected locations have already been procured and tested at the INESC-ID Labs. Some basic details of the acquired chargers and their respective installation location are provided in Table 1.

Table 1 – Details of the acquired chargers and their respective installation location.

Charge Details	Installation Location(s)
Alfen EVE Single Pro – 22kW – three phases	Location 1, Location 2
Alfen EVE Double Pro – 22kW – three phases	Location 3, Location 4
Latinki11 Home - 11 kW Bidirectional – three phases	Public parking lot

2.1.3.2. Installation services procurement

The procedure for deploying EVSE within the AHEAD WP9 demonstration activities in the Funchal pilot follows a structured, end-to-end "turnkey" approach that covers design, installation, commissioning, and post-deployment support.

As part of the procurement process, a minimum of three qualified companies will be invited to submit proposals, ensuring a competitive and transparent selection procedure, from which one contractor will be selected based on technical and financial criteria.

The scope includes the preparation of the electrical installation design, submission and management of the Technical Information Request (TIR) to define the connection to the public distribution network, and the execution of all required electrical and civil works. These activities comprise the installation or adaptation of distribution cabinets, integration of protection and metering systems, routing and installation of power cabling, and the mounting of charging equipment and associated infrastructure. Civil works are adapted to site-specific conditions and include trenching, pavement intervention and reinstatement, or integration within existing structures, ensuring compliance with applicable regulations, safety requirements, and manufacturer specifications.

Following installation, the procedure includes certification of the electrical installations by an accredited entity, formal connection to the public grid, and the execution of Site Acceptance Tests (SAT) to validate the correct operation, safety, and interoperability of all components. Upon successful commissioning, the infrastructure enters an operational monitoring phase, during which performance is assessed, and technical support is ensured through predefined maintenance provisions.

The execution of installation works is planned for June 2026 (with exact dates to be agreed between the parties), with a maximum duration of 15 consecutive working days, ensuring that all equipment is installed and commissioned prior to the start of the monitoring phase.

2.1.4. Commissioning activities

Commissioning activities are already underway, using the two fast chargers installed at the EEM premises as a basis (Figure 10). Once fully operational, the same solution will be replicated to the other four chargers installed in the street.

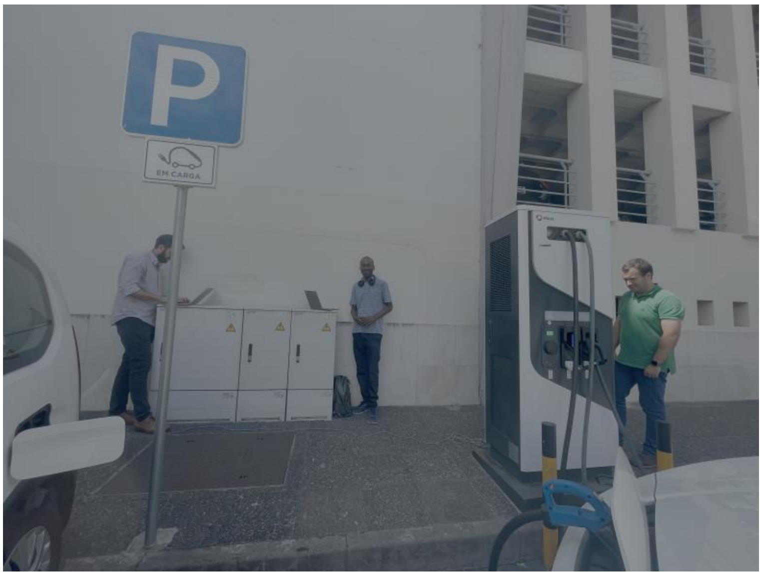


Figure 10 – Works being carried out during the commissioning of the EEM/EMACOM Fast Chargers.

The key component of this commissioning is the OCPP Proxy that sits between the charger and Mobi.E. In simple terms, the OCPP proxy has three main responsibilities:

1) Handling authentication with Mobi.E and forwarding all the communications between the charger and Mobi.E, and vice-versa. This is a critical aspect since this is what enables the charger to be used by anyone, independently of being active participants in the AHEAD project.

2) Forwarding all the communications, in particular meter values, to the *BirdsEyeView* platform when a charging session is ongoing. This is also critical, as it will enable us to collect real-time charging session data for the demonstrator.

3) Forwarding smart charging requests to the charger (e.g., reduce charging speed), and sending the responses back to the *BirdsEView* platform. This action will only be performed for EV drivers who are active participants in the AHEAD project.

A diagram illustrating the original and the new process can be seen in Figure 11.

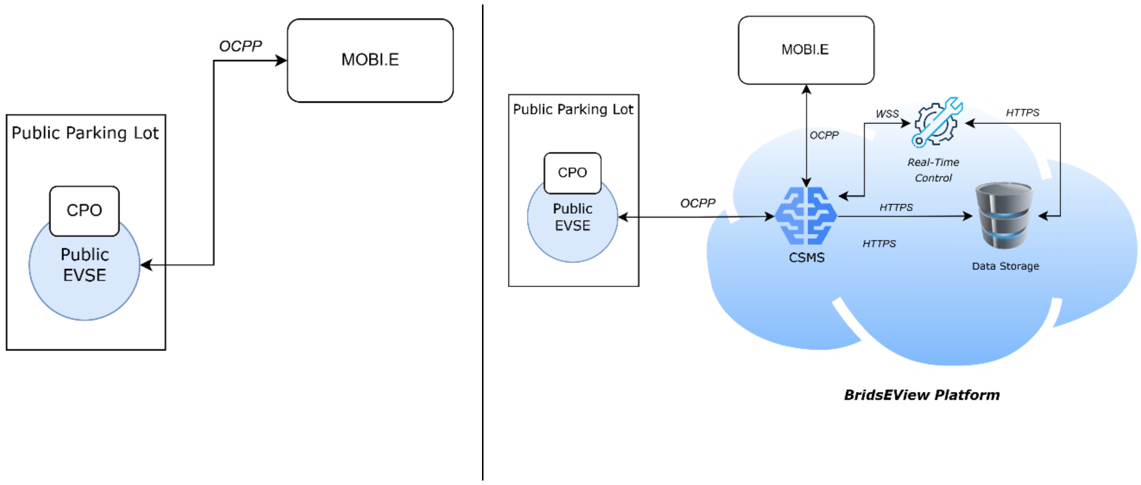


Figure 11– Process for integration with MobiE: original with direct communication (left), AHEAD with communication via OCPP proxy (right).

2.2. Funchal: Touristic Port Area

2.2.1. Initial setup

The site is in the touristic port area of Funchal's city centre and primarily supports maritime leisure operations, including whale-watching activities. The infrastructure can accommodate up to approximately 20 vessels, depending on their size, with only one vessel currently operating in hybrid mode. The port is equipped with electric and water distribution units to meet the vessels' operational requirements and is supplied by a nearby secondary substation that also provides power to other local services.

2.2.2. Marina technical assessment

A preliminary technical assessment was conducted to evaluate the existing electrical infrastructure in the Funchal port area's capability to support the electrification of maritime operations, with particular focus on catamaran charging. The assessment was based on the analysis of the substation's yearly load profile supplying the relevant area. The transformer serving the site has a rated capacity of 800 kVA, while the measured annual load profile for 2025 shows that demand remains significantly below this limit for most of the year, with typical operation at relatively low load levels and peak values reaching approximately 500 kW (Figure 12).

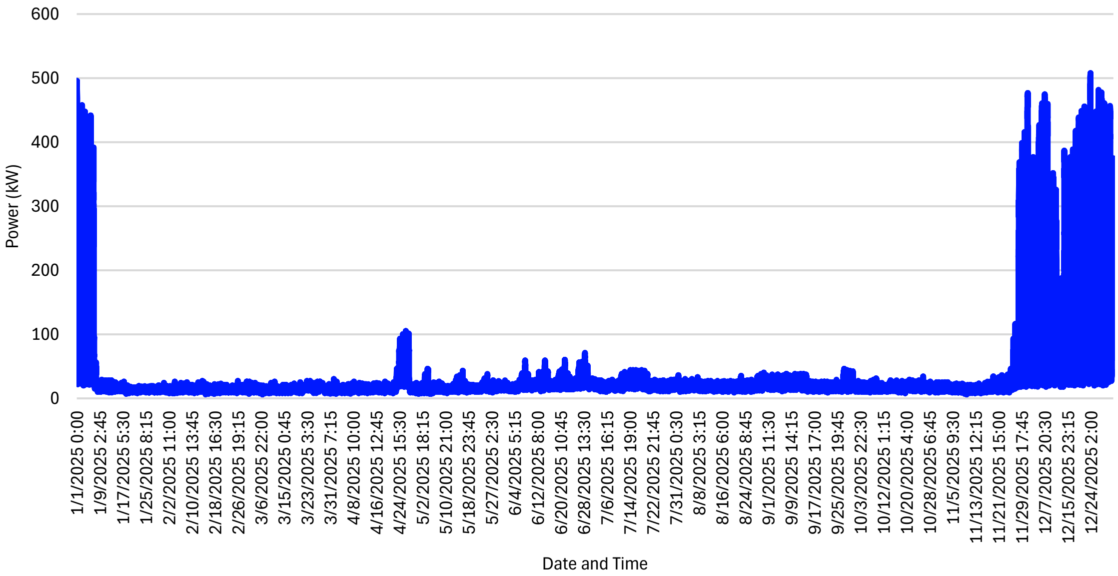


Figure 12 – Yearly active power demand of the Funchal port area substation in 2025, showing the existing loading conditions relative to the electrification needs of maritime operations.

A notable increase in demand is observed during the month of December, which is associated with seasonal activities and increased electricity consumption due to Christmas festivities. While these periods result in higher loading of the transformer, the observed demand remains below the rated capacity, indicating that a margin of available capacity is maintained even under peak seasonal conditions. However, these periods represent more constrained operating conditions, where additional loads should be carefully managed.

Within the scope of the AHEAD demonstration, the operational assumption is that a single hybrid vessel will be considered for charging (up to 22 kW). Under this controlled scenario, the additional demand introduced by vessel charging is expected to be modest relative to the existing load levels. As such, the integration of the charging system is considered technically feasible without requiring reinforcement of the existing infrastructure, particularly when charging is scheduled outside peak demand periods or managed through coordinated control strategies.

From a forward-looking perspective, the port presents a significantly higher electrification potential, particularly in the context of tourism-related maritime activity. In a future scenario, the infrastructure may be required to support the charging of up to 20 fully electric catamarans. Such a scenario would introduce substantially higher and more concentrated loads, especially during already constrained periods such as December, and would likely require a combination of advanced energy management strategies and infrastructure reinforcement. This highlights the importance of the AHEAD project in enabling scalable and intelligent electrification pathways for port environments.

2.2.3. Custom EVSE development activities

Following the technical assessment of the site, the next step focuses on the design and development of a custom charging solution tailored to the specific requirements of the Funchal port demonstration. This includes the definition of system architecture, integration with the existing electrical infrastructure, and the implementation of control strategies to support efficient and scalable vessel charging within the AHEAD framework.

An initial reference architecture for the charging solution was developed to guide early design considerations, as illustrated in Figure 13. This preliminary concept was based on a single-phase V1G charging configuration, incorporating multiple sockets, basic protection elements, and communication capabilities for monitoring and control (e.g., via Wi-Fi and MQTT). While this design reflects an early-stage approach focused on conventional unidirectional charging, it provided a useful foundation for identifying key system components, communication requirements, and integration challenges.

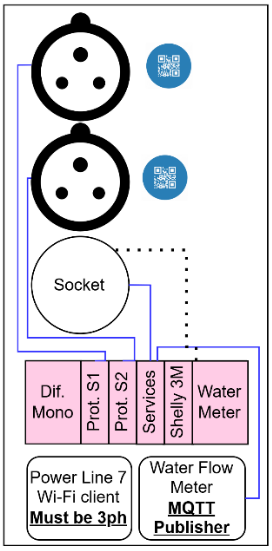


Figure 13 – Reference architecture of the charging solution.

2.3. Funchal: Private Multi-Unit Garage

This subsection describes the installation and commissioning activities carried out in a private multi-unit garage within a residential building in Madeira. The site comprises multiple households connected to a shared low-voltage network supplied through a secondary substation, with each household equipped with its own PV system.

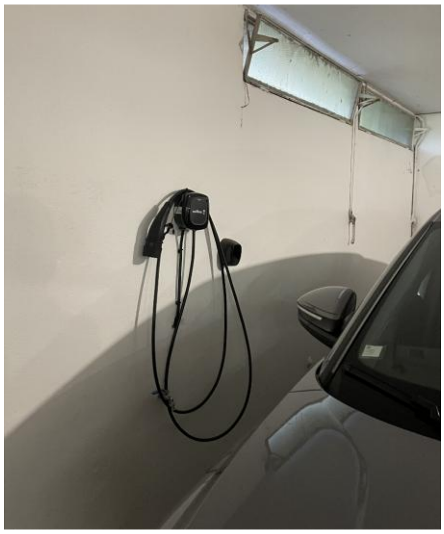
2.3.1. Initial Setup

Prior to the intervention, the site presented a limited level of controllability and observability. The EV charging infrastructure consisted of a single EVSE Wallbox Pulsar installed in the common services area. Although residential PV systems were already in operation, no detailed monitoring infrastructure was available to capture power flows at different points of the installation. As a result, the ability to implement coordinated energy management strategies across the system was constrained. **Error! Reference source not found.** shown details about the pre-existing infrastructure.

Table 2 – Pre-Existing Infrastructure

Device Type	Description	Capacity	Function	Location
EVSE	Wallbox Pulsar	7.2kW single phase	Manage EV charging	Common services garage area
PV system	Photovoltaic unit in each household	PV power up 0.5kWp	Local generation per household	Individual household
Electrical Network	Shared LV connection	23kW	Power supply to all units	Secondary substation connection

Figure 14 presents the initial configuration of the private garage prior to the project intervention. The installation included an existing EVSE unit and a conventional electrical distribution panel, with no dedicated monitoring infrastructure or advanced control capabilities. This setup represents a typical residential environment with basic EV charging functionality but limited visibility and coordination of energy flows.



(a) **(b)**

(c)

Figure 14 – Initial Configuration of the Private Garage: (a) PV unit installed; (b) Installed EVSE-Wallbox unit; (c) Existing electrical distribution panel

2.3.2. Installation Activities

The installation phase aimed to enhance both the monitoring capabilities and the controllability of the site. A distributed set of smart meters (highlighted in blue in Figure 15) was installed across the electrical network, covering individual households, PV generation units, and common service loads. This instrumentation enables real-time measurement of consumption and generation at the three phases, providing detailed visibility of the electrical behaviour of the installation. In addition to the existing EVSE Wallbox Pulsar, the EV charging infrastructure was expanded through the installation of one EVSE unit from Alfen Eve Single (7.2 kW) and two OCPP-compatible power outlets (3.6 kW each). A smart plug was also deployed to enable monitoring operation of additional PV unit. All newly installed controllable devices are connected within the common services branch of the network.

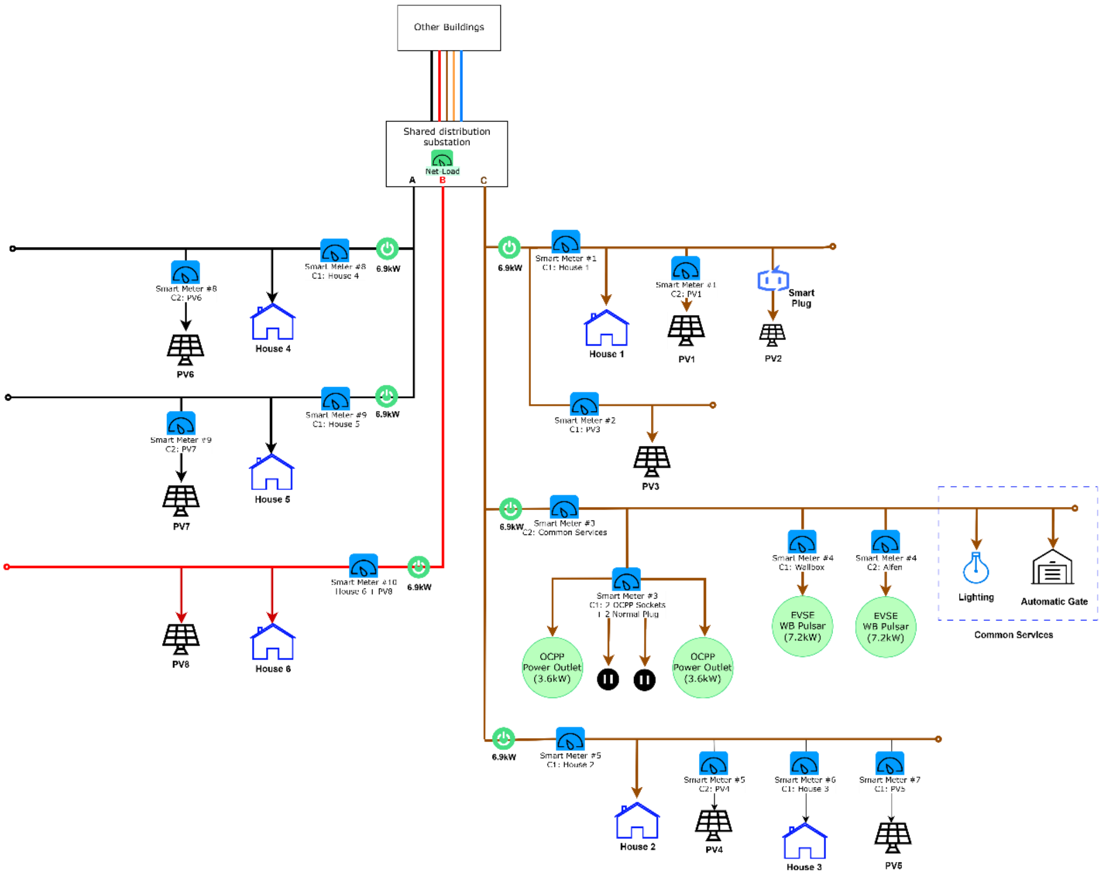


Figure 15 – Architecture of the Private Multi-Garage Low-Voltage

Error! Reference source not found. presents the set of EV charging and monitoring devices installed in the private muti-garage and across the associated residential units. The deployed infrastructure combines EVSE equipment with a distributed metering system, enabling detailed observation of power flows at different levels of the installation.

At the building level, a three-phase smart meter (Shelly Pro 3EM 120A) is installed to measure the overall net load of the installation, providing a global view of power exchange at the connection point with the low-voltage network. This measurement is essential to assess the aggregated impact of EV charging, residential consumption, and PV generation.

At the household level, several single-phase smart meters (Shelly Pro EM-50) are deployed to monitor both consumption and local PV production. In most cases, the two available channels are used to separately capture load demand and generation, enabling a detailed characterisation of prosumer behaviour. Additional metering points are installed to capture specific generation sources or consumption branches where needed.

Within the garage and common services area, dedicated metering is implemented to monitor the EV charging infrastructure and associated loads. Specific smart meters are assigned to the OCPP-compatible power outlets and standard sockets, as well as to the individual EVSE units (Wallbox Pulsar and Alfen), allowing disaggregated measurement of EV charging demand. This level of granularity supports precise evaluation of charging behaviour and control actions. All controllable charging devices, including the EVSEs and OCPP-compatible plugs, are connected to phase C, where active energy management is implemented. Accordingly, most of the detailed monitoring associated with controllable assets is concentrated on this phase. In contrast, measurements in the remaining phases (A and B) are primarily used for monitoring purposes, providing complementary information on the overall system behaviour and enabling the assessment of phase imbalance and load distribution. Overall, the deployed metering architecture ensures high-resolution visibility of the system, supporting both real-time monitoring and the evaluation of coordinated charging strategies in a multi-user residential environment.

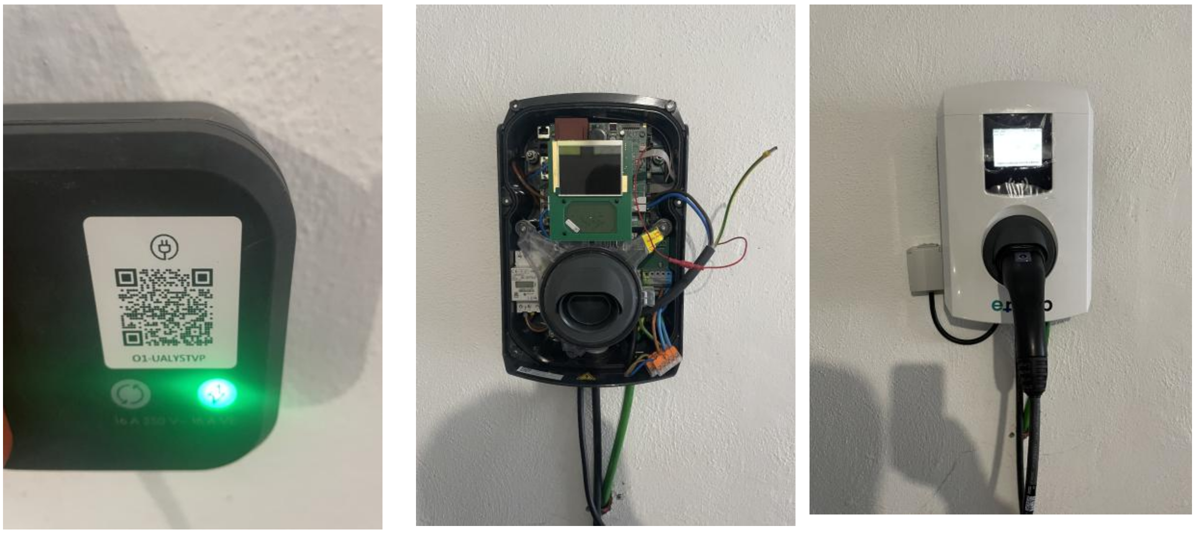
Table 3 – Installed EV Charging Infrastructure and Monitoring Devices

Device Type	Model	Capacity	Function	Location
Smart Meter Tri-phase	Shelly Pro 3EM 120A	120A per intensity transformer,	Measure building overall installation (net-load)	Private Building three-phase
Smart Meter single phase #1	Shelly Pro EM-50	50A per intensity transformer, two channels	Measure House 1 power consumption (channel 1) and power production (channel 2)	House 1 – Phase C
Smart Plug	Shelly Plug S MTR	230V, 2.5kW	Measure extra Power production connected to it	House 1 – Phase C
Smart Meter single phase #2	Shelly Pro EM-50	50A per intensity transformer, one channel	Measure extra power production	House 1 – Phase C
Smart Meter single phase #3	Shelly Pro EM-50	50A per intensity transformer, two channels	Measure 2 OCPP Sockets and two normal sockets (channel 1) Common Services (channel 2)	Garage – Phase C
Smart Meter single phase #4	Shelly Pro EM-50	50A per intensity transformer, two channels	Measure EVSE WB Pulsar (channel 1) and EVSE Alfen (channel 2)	Garage – Phase C
Smart Meter single phase #5	Shelly Pro EM-50	50A per intensity transformer, two channels	Measure House 1 power consumption (channel 1) and power production (channel 2)	House 2 – Phase C
Smart Meter single phase #6	Shelly Pro EM-50	50A per intensity transformer, one channel	Measure House 3 power consumption	House 3 – Phase C

Smart Meter single phase #7	Shelly Pro EM-50	50A per intensity transformer, one channel	Measure PV power production	House 3 – Phase C
Smart Meter single phase #8	Shelly Pro EM-50	50A per intensity transformer, two channels	Measure House 4 power consumption (channel 1) and power production (channel 2)	House 4 – Phase A
Smart Meter single phase #9	Shelly Pro EM-50	50A per intensity transformer, two channels	Measure House 5 power consumption (channel 1) and power production (channel 2)	House 5 – Phase B
Smart Meter single phase #10	Shelly Pro EM-50	50A per intensity transformer, two channels	Measure House 5 power consumption (channel 1) and power production (channel 2)	House 6 – Phase B

Figure 16 presents the main components of the private garage low-voltage installation, including the electrical distribution board, communication cabinet, OCPP-compatible plugs, and EV charging infrastructure. The setup integrates monitoring and controllable devices, enabling data acquisition and coordinated operation of EV charging within the residential environment.

(a) **(b)** **(c)**



(d) (e) (f)

Figure 16 – Architecture of the Private Multi-Garage Low-Voltage: (a) Main electrical distribution board; (b) Internal view of the communication and wiring cabinet; (c) OCPP-compatible plug in the garage wall; (d) OCPP-compatible plug working validation; (e) EVSE Alfen installation;(f) Installed EVSE unit (Alfen).

2.3.3. System Architecture and Integration

As illustrated in Figure 155 the installation is structured around a shared connection to the secondary substation, with multiple branches supplying residential units and common services. Each household is associated with local PV generation and monitored through dedicated smart meters, while the common services branch aggregates EV charging infrastructure. The deployed metering infrastructure allows the observation of power flows at different hierarchical levels of the system, including household consumption, PV generation, and aggregated demand at the common services level. This architecture enables a comprehensive representation of the system state, supporting both local analysis and higher-level coordination strategies.

2.3.4. Commissioning and Operation

The commissioning process involved the validation of all installed components, including electrical verification, communication setup, and functional testing. The smart meters were calibrated and validated to ensure accurate measurement of power flows across the system. All EV charging devices and OCPP-compatible plugs were configured and tested to confirm correct operation and communication with the backend system. Interoperability between the different charging technologies was verified, including the integration of the newly installed devices with the pre-existing Wallbox charger. Communication through OCPP protocols was successfully validated, ensuring reliable device status reporting and remote controllability. Following commissioning, the site evolved into a fully instrumented and partially controllable environment. Within the scope of the project, active energy management is implemented exclusively on phase C of the distribution system, where all controllable devices, namely the EVSEs and OCPP-compatible power outlets, are connected. The remaining phases are not subject to direct control and are instead used as monitoring inputs, providing contextual information on the overall system behaviour. This configuration enables the evaluation of coordinated charging strategies under phase-specific constraints, including the impact on phase loading and the interaction between controlled and non-controlled elements of the network.

2.3.5. Operational Relevance

The resulting setup provides a realistic and representative testbed for analysing EV charging integration in multi-user residential environments with shared infrastructure and distributed energy resources. It enables the assessment of load management strategies, the interaction between EV demand and PV generation, and the effectiveness of coordinated control under practical deployment constraints.

This subsection describes the installation and commissioning of EV charging infrastructure in a private multi-unit residential garage in Funchal, supplied through a shared electrical connection and integrated with residential loads, common services, and distributed photovoltaic generation.

As illustrated in the system layout, the site includes multiple charging devices with different power ratings, namely OCPP-enabled power outlets (sockets allowing control by On-OFF commands) and dedicated EVSEs, together with monitoring devices deployed at different points of the installation. This configuration enables detailed observation of consumption and generation patterns across the residential units and the common services area.

2.4. Lisbon: Semi-Public Parking Lot

This section details the deployment of advanced charging infrastructure at the EDP Labelec campus in Sacavém, Lisbon. This site serves as a semi-public demonstrator for testing parking management strategies considering EV user requirements, power consumption and generation (local PV), and participation in flexibility services.

2.4.1. Initial Setup

The Lisbon demonstrator is hosted within a large parking lot in a laboratory campus connected to a 10 kV medium voltage grid via a private 630 kVA transformer. The current parking lot features 60 charging points (ETREL INCH Pro 11 kW), of which 4 units will be directly monitored by the AHEAD project. This infrastructure will be complemented with the installation of two bidirectional EVSEs (11 kW), and one automated charging pad (11 kW).

A critical component of the pre-existing setup is the main electric vehicle distribution board (QGVE), which was installed in June 2025 as part of an earlier project. To support the specific deployment requirements of the AHEAD project, the QGVE already includes a dedicated 63 A circuit breaker reserved for the connection of the new secondary distribution panel, designated as QVE. The demonstration and monitoring phase for this site is scheduled to run from May 2026 to May 2028, following the completion of the hardware installation and commissioning activities.

(a)

(b)

Figure 17– Aerial view of the parking lot in EDP campus (a) and existing chargers (b)

2.4.2. Installation activities

The installation phase for the Lisbon pilot follows the integration of 2 bidirectional chargers (1x CHAdeMO PRE-Heliox 11 kW and 1x CCS2 InterControl Latinki 11), 1 EASELINK Matrix pad automated charger and the respective retrofitting of a compliant EV and a distributed monitoring system.

The primary activities involved in the physical deployment include:

- Secondary distribution board: This cabinet is supplied by a 63 A circuit from the pre-existing main distribution board (QGVE) and is equipped with individual 16 A circuit breakers and Type B RCD for each charger.
- Civil Works and Mounting: Physical infrastructure deployment requires the execution of a concrete foundation for the pedestal that hosts the two bidirectional chargers. For the automated wireless system, a non-intrusive metal plate is fixed to the existing grass grid pavement using specialized clamps to support the Matrix Charging pad.

- Cabling and Connectivity: The installation includes the passing of cables on already pre-installed cable routing of both power and communication cables between the QVE panel and the charging spots. Each charger is connected via RJ45 Ethernet cabling to a central communication hub within the distribution board.

- Metering and Communication Hardware: To enable autonomous data collection, three Shelly smart meters (or equivalent) are installed within the QVE to provide individual measurements for each charging unit. The communication layer is completed with the installation of a router and switches to facilitate real-time data exchange with the project's control platform. Additionally, two smart meters will be installed within the inverter of the PV installation (22 kWp) and the main switchboard of the office building for load management.

The execution of these works is scheduled for May 2026, involving already contracted technical teams to ensure that all equipment is installed while meeting the project's technical requirements. Following the completion of this infrastructure stage, the project will initiate the vehicle-side integration required for the automated charging system. This will involve the retrofit of a compliant EV (Hyundai IONIQ5), which will be made with a partnership with Hyundai Portugal. This retrofitted vehicle will be equipped with the integrated bottom-mounted connector necessary to test the functionality of the Easelink Matrix Charging pad.

a) b) c)

Figure 18 – Chargers to be installed in the Lisbon demo (a) and the respective meters on the PV inverter (b) and the main switchboard of the office building (c)

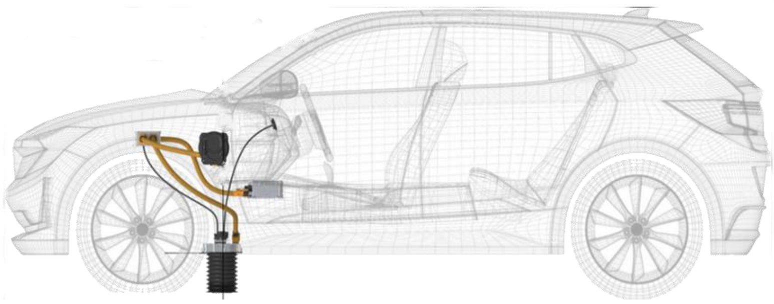


Figure 19 – Installation of EASELINK matrix vehicle pad

2.4.3. System Architecture and Integration

The Lisbon pilot is fully integrated into the overarching birds-EView platform, which serves as the unified control and data access system for the entire demonstrator. The system architecture incorporates three distinct charging technologies (CHAdeMO, CCS2 and automated). To achieve the pilot's goal to manage local generation and consumption, a distributed metering system is implemented within the charging points, the local PV inverter and the main switchboard of the office building.

2.4.4. Communication and operation

Regarding communication protocols, the InterControl Latinki 11 bidirectional charger follows OCPP 2.0.1, while the remaining units (CHAdeMO PRE-Heliox and the Easelink Matrix Charging automated system) uses OCPP 1.6. To provide connectivity for the site, the installation includes a central communication hub equipped with a main router (e.g.: Teltonika TRB140) and switches (e.g.: Teltonika TRB140). The PV inverter and the main switchboard meters will use 4G/LTE meters to feed real-time operational data into the project's birds-EView control platform.

3. FUNCTIONAL ARCHITECTURE OF WESTERN EUROPE DEMONSTRATOR

This section presents the functional architecture of WED which shows how different system components work together to manage EV charging and energy distribution. The architecture establishes the control system and communication structure and data interchange framework which uses existing equipment and systems described in earlier sections. The system tests focus on achieving two main objectives which involve enabling different types of devices to work together and establishing an operational framework that supports reliable system performance. The architecture requires integration between three operational levels which include street-level devices and main control systems and coordination functions. The framework enables organizations to develop sophisticated control systems while it provides tools for continuous system observation and testing organizational flexibility in actual business environments. The control platform of the WED is structured as a multi-layered system designed to enable real-time monitoring, coordinated control, and scalable integration of heterogeneous devices and data sources. As illustrated in Figure 20, the architecture follows a modular approach, where distinct functional layers interact through well-defined communication interfaces and protocols. More details about the different layers are available in the following sessions.

3.1. Data Sources Layer

The data source layer comprises all physical devices, simulated assets, and external digital services connected to the WED. This layer represents the origin of operational, measurement, authentication, and user-related data that feed the control platform. As illustrated in Figure 20, the data sources include public and private EV charging infrastructures deployed across the demonstrator sites, namely the Funchal port chargers, Funchal AHEAD charging stations, Funchal garage charging stations, Lisbon AHEAD charging stations, and Lisbon EDP charging stations. These charging assets communicate mainly through OCPP [3], enabling the exchange of charging session information, charger status, metering values, and operational events. The layer also includes smart meters deployed in the demonstration sites, which provide measurements of power consumption, PV production, common services, and aggregated loads. These devices communicate through MQTT, allowing the platform to receive near real-time monitoring data from the electrical installation.

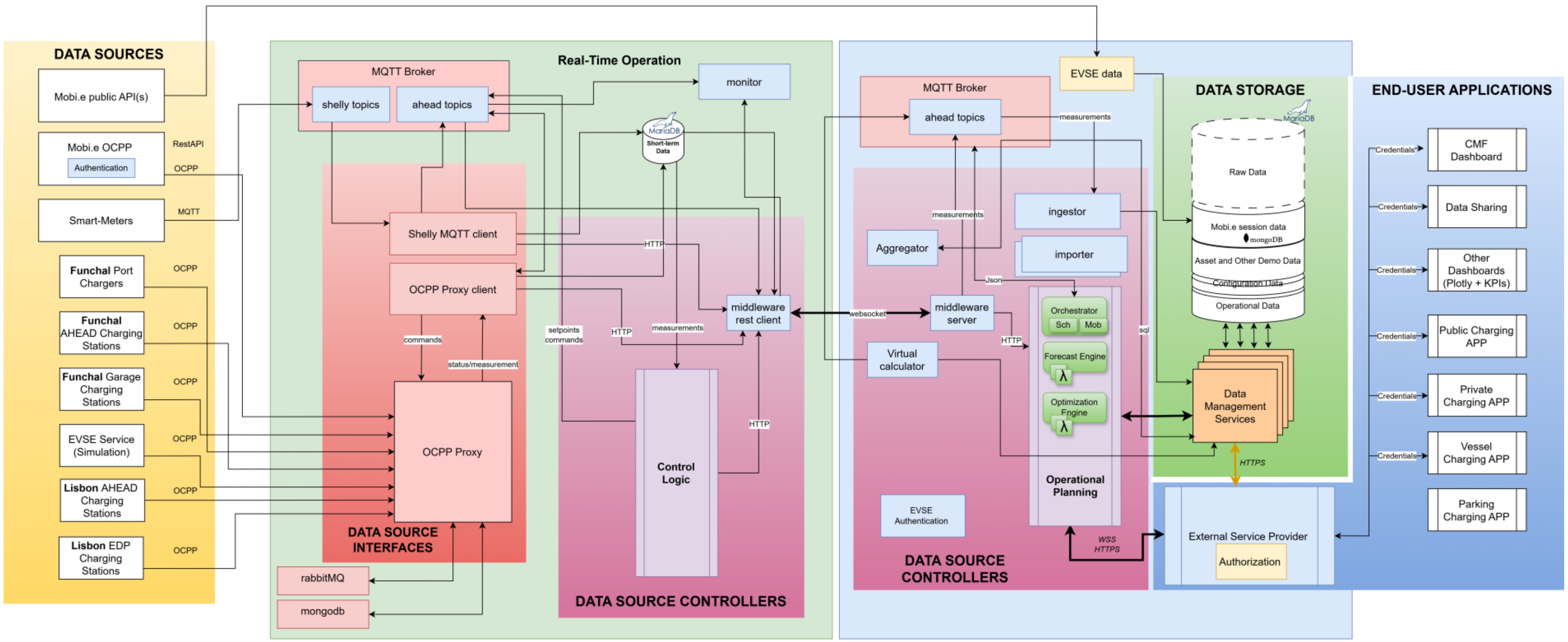


Figure 20 – Functional Architecture of the Western Europe Demonstrator Control Platform

In addition to physical assets, the architecture includes simulated EVSE services. These simulated sources reproduce charging station behaviour and are used to test platform functionalities, validate communication flows, and support scenarios that cannot be fully reproduced with physical devices during early integration stages. External services are also part of this layer. The Mobi.e public APIs provide access to information related to the Portuguese public charging ecosystem, while the Mobi.e OCPP interface supports authentication and interaction with public charging infrastructure. REST APIs are used for request–response interactions, such as retrieving external data, exchanging configuration information, and supporting integration with user-facing services.

3.2. Data Source Interfaces Layer

The data source interfaces layer is responsible for bridging the field devices and the upper control services, ensuring that heterogeneous protocols and device-specific communications are translated into a unified interaction model for the control platform. In the architecture presented in Figure 20, this layer is mainly composed of the OCPP Proxy, the OCPP Proxy client, the Shelly MQTT client, and the supporting RabbitMQ and MongoDB services.

The OCPP Proxy is the main interface with the EV charging infrastructure. It maintains communication with the different OCPP-enabled EVSE deployed across the demonstrator and is responsible for receiving status notifications, transaction data, and operational measurements from the EVSEs. At the same time, all communications are forwarded to OCPP Proxy client. OCPP-Proxy client dispatches commands and control requests from the upper layers towards the EVSEs via OCPP Proxy. In this sense, the OCPP Proxy and OCPP Proxy client act as the protocol-specific gateway between the charging infrastructure and the platform, converting EVSE communications into a form that can be consumed by the control logic and the real-time services.

3.3. Data Source Controllers

The data source controllers layer serves as the platform's main real-time control system which unifies data collection with decision processes and control system operations. The layer shown in Figure 20 handles the conversion of measurement streams into control signals which manage the EV charging operations throughout the demonstrator system. The control logic module serves as the main component of this layer because it processes real-time data which the data source interfaces layer sends to it. The control logic uses these system inputs to determine control actions which include establishing charging setpoints and creating operational commands that it sends back to the field devices. The middleware REST client enables external component interactions by serving as the communication gateway which connects control logic to upstream and downstream services. The system receives measurements and updates through WebSocket communication which allows the control layer to monitor system state changes. The system sends setpoints and control commands which the control logic generates to the lower layers so that devices can execute them.

This layer implements short-term data storage to enable real-time operations through its ability to store current measurements and system states. The system uses temporary storage to provide swift access to data which supports control decisions while minimizing the need for external databases and enhancing protection against communication interruptions. The system enables users to monitor system performance through real-time visualisation and monitoring service interactions. The layer uses MQTT as its primary communication method which enables components to exchange data in a structured and real-time manner. The system architecture enables systems to operate nearly in real time because it allows measurement processing and control functions to run within brief time intervals, which creates a system that can respond to changes and adapt to new conditions. The platform operates through closed-loop control which connects measurement acquisition with data processing and control execution. The system delivers rapid response times together with effective coordination abilities to control electric vehicle charging operations in an environment that undergoes constant changes while it connects local charging optimization with higher-level planning and service operations.

3.4. Operational Planning and Advanced Services Layer

The platform gains enhanced operational capabilities through this layer which enables users to perform both real-time operations and day-ahead and mid-term operational planning through its advanced data processing and forecasting and optimisation capabilities. The system creates a dedicated pathway which processes unprocessed measurement data to produce optimal charging schedules together with synchronized control methods as shown in Figure 20. The ***ingestor*** begins the data processing workflow by receiving measurement data from lower layers which include both EVSE data via MQTT "ahead topics" and it ensures that the structured data acquisition process works effectively. The platform might deploy multiples instances of ***importer.*** The components of type ***importer*** process the data from external sources by transforming it into standardized formats which include JSON structures, to ensure that downstream systems can handle the data without any issues. The external sources include prices information, weather forecast and historical weather data. The ***aggregator*** combines measurement data from each sensor within a time interval into a single record. Typicaly, a 5-minute interval is used to create complete datasets which show how the system operates by displaying total load and generation and flexibility potential in a predictable manner. The ***middleware server*** works as the main control centre for this layer, which enables data processing components to communicate with high-level services. The system enables data to flow in both directions through its HTTP and WebSocket interfaces, which allow users to make synchronous requests while receiving streaming updates. The ***virtual calculator*** and other components of the system create additional virtual measurements and planning variables which serve as essential data for the planning and optimisation processes.

The ***operational planning*** module acts as the main component of this layer because it connects both the forecast engine and the optimisation engine. The forecast engine generates predictions of key variables, such as load demand, EV charging behaviour, and local generation (e.g., PV production), which serve as essential decision-making inputs. The ***optimisation engine*** uses these forecasts to determine the best charging schedules and control strategies while assessing system limitations and user preferences and flexibility needs. An ***orchestrator*** controls the process execution by handling various operational states which include scheduled planning and mobility-driven scenarios while maintaining alignment between forecasting and optimisation and system limitations. The system transfers its generated schedules and control actions to lower system components which implement these actions through their real-time control systems. This layer provides authentication services through its implementation of EVSE authentication while establishing secure communication links to external systems through HTTPS and WebSockets, which enable the system to verify platform access and exterior service requirements during planning activities. The system allows organizations to move from using reactive control techniques to operating their systems through predictive optimized operations. The system supports advanced energy management strategies while enabling EV charging infrastructure to function together with all other elements of the energy system.

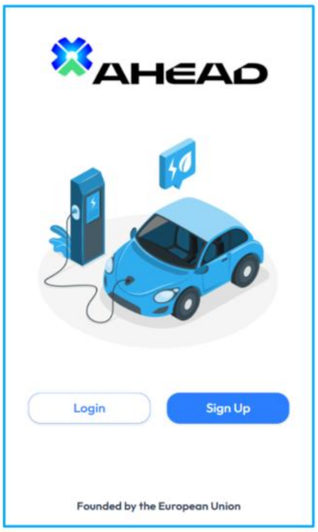
3.5. Data Storage Layer

The platform's data storage layer establishes permanent structured data storage which maintains all platform-generated data for both operational use and analytical processing requirements. The storage system shown in Figure 20 consists of multiple data categories which include raw data, Mobi.e session data, asset, demonstration data, configuration data, and operational data. The system uses a layered structure which separates unprocessed measurements from processed and context-enriched datasets, which enables effective data management through streamlined data retrieval operations. Organizations use raw data from field devices and external systems to maintain traceability through offline analysis, while they employ processed and operational data to facilitate real-time decision-making and system monitoring activities. Configuration data enables systems to maintain uniform operation by storing essential parameters which define asset and user and operational environment settings. The storage system uses a MongoDB-based database which provides the system with capabilities to manage different data types and scale its storage resources. The data management services create a structured system for accessing stored data which handles all processes from data ingestion through validation and transformation to final data retrieval. The platform uses these services to maintain data integrity and consistency while ensuring interoperability, as they provide secure data access through HTTPs interfaces to all internal and external users.

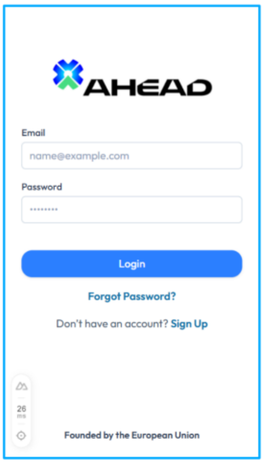
3.1. End-User Applications Layer

This layer establishes connections with external service providers to handle authorization and authentication processes, which ensures that data access and system interactions occur in accordance with security requirements and user permissions. The end-user applications layer provides the interface between the platform and its users, enabling access to functionalities through a set of dedicated applications and dashboards tailored to different stakeholders and use cases. The available resources for users include the CMF dashboard and data sharing services and analytical dashboards which feature Plotly-based KPIs and dedicated applications for public charging, private charging, vessel charging, and parking management. All applications use secure communication channels to connect with the platform while they depend on credential-based access control mechanisms. The system grants users' access to data and services according to their specific job responsibilities. The mobile applications provide users with the ability to track system performance while they display energy and charging information and set up charging sessions and access platform services through an easy-to-use interface.

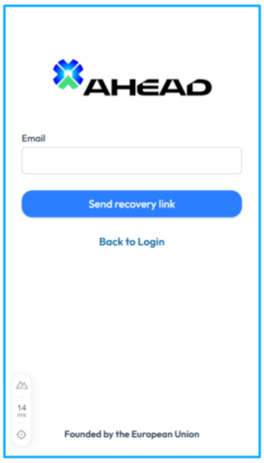
The mobile application enables users to enter their EV charging preferences which include their SoC required, SoC target, charging preferences, among others. Through the mobile application users can send their charging preferences, their availability, and their participation details about specific services to the platform. The control platform uses these inputs for decision-making which leads to development of energy management strategies that focus on user needs and adapt to real-time conditions. The application provides secure and dependable communication with the backend system by using standard interfaces to exchange data between systems. The description of the different user screens of the application will be detailed below, highlighting how they enable intuitive navigation and support a seamless and user-friendly charging experience.



Landing Page: The mobile application first screen functions as the entry point which lets end-users use the authentication system. The application displays AHEAD project branding. End-users can choose between two options by selecting existing accounts through *Login* and creating new accounts through *Sign Up*. The application layout uses a basic design which enables end-users to access its features while providing a straightforward interface for their needs.

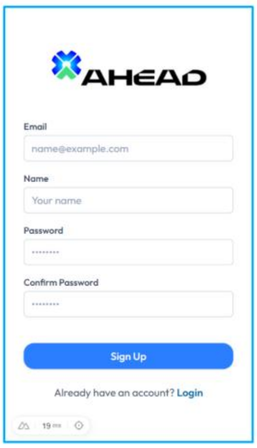


LOGIN

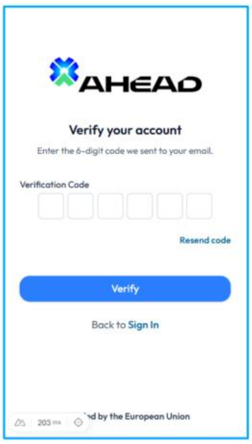


FORGOT PASSWORD

Login Pages: The screens display the user authentication interfaces which belong to the mobile application. The login page allows registered users to access the platform by entering their credentials like email and password, with additional options for password recovery and account registration. The *"Forgot Password*" screen enables users to request a recovery link by providing their email address, which ensures secure account access management. The two authentication interfaces use a straightforward design which enables users to navigate the system and authenticate their identities without difficulty.



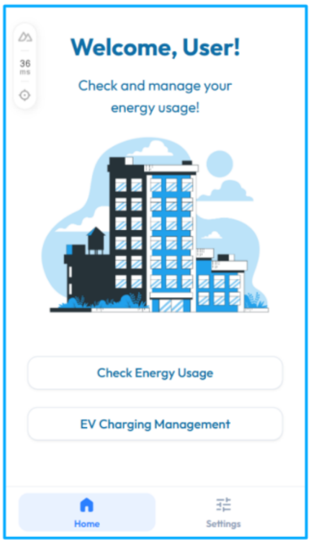
SIGN UP



VALIDATION

Register Pages: The mobile application presents the user registration and account verification process through a set of dedicated interfaces. It is important to note that the account creation process is exclusively required for users accessing the public charging infrastructure. In contrast, users within the residential building are expected to already have pre-established accounts, as these are managed beforehand within the system. The sign-up interface enables new public users to create an account by providing essential information such as email, name, and password, ensuring a secure and structured onboarding process. Following registration, the validation screen allows users to verify their account by entering a code sent to their email, supporting authentication and enhancing security.

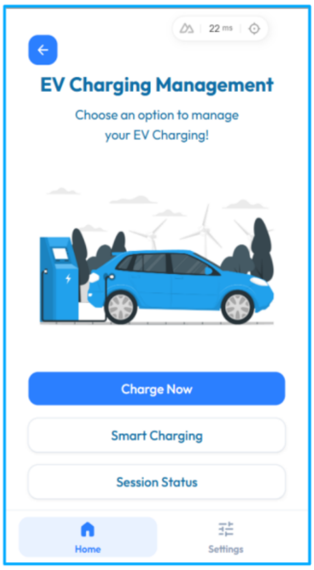
Home and Energy Page: these screens show the primary dashboard together with the energy tracking system of the mobile application. The home screen serves as the central navigation point, allowing users to access key functionalities such as energy usage monitoring and EV charging management. The system offers users direct access to its core functions through its main service overview. The energy usage screen enables users to visualise and analyse their energy consumption and production. Users can select different timeframes which include daily and weekly and monthly options to see energy profiles through graphical displays.



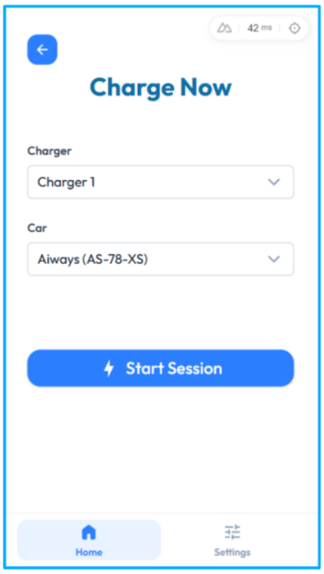
HOME

CHECK ENERGY
(TOP OF THE PAGE)

EV charging Pages (*EV charging Management and Charge Now)*: These screens present the EV charging management interface of the mobile application. The EV Charging landing page provides users with access to the main charging functionalities, including immediate charging, smart charging options, and session monitoring. It serves as the central entry point for managing EV charging activities. The "*Charge Now*" screen allows users to initiate a charging session by selecting the desired charger and associated vehicle immediately, Providing the user with the right to charge their car, in case of emergencies, at any time they wish, without being limited by waiting for a smart charging schedule. Once configured, users

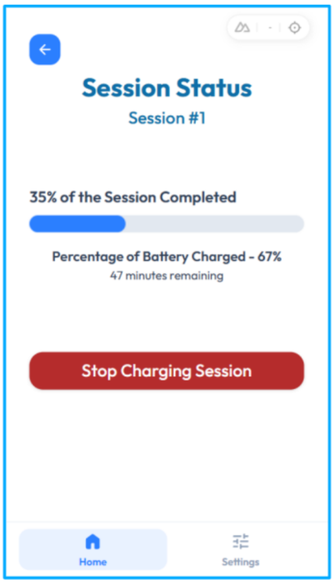


EV CHARGING
LANDING PAGE

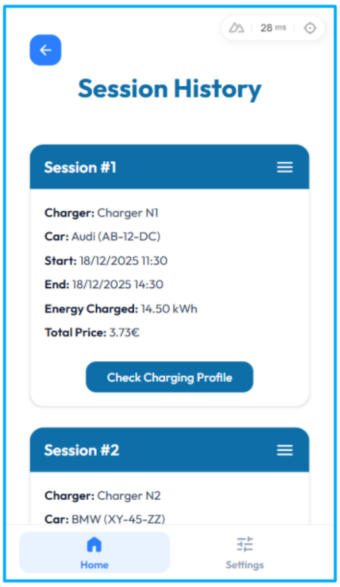


CHARGE NOW

can start the charging session directly through the application.

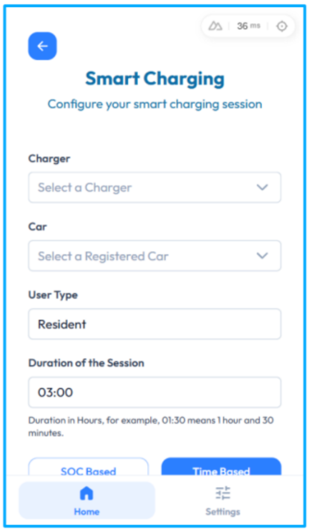


SESSION STATUS



SESSION HISTORY

Session Status and History. These mobile application screens show both session monitoring capabilities and session history tracking features. The session status screen provides real-time information about an ongoing charging session, including progress, battery level, estimated remaining time, and the option to stop the session if needed. Users could observe their charging process while they control its progress. The session history screen displays a record of past charging sessions, including key details such as charger used, vehicle, start and end times, energy consumed, and total cost. Users can also access additional information, such as the charging profile, enabling a more detailed analysis of their charging behaviour.



SMART CHARGING
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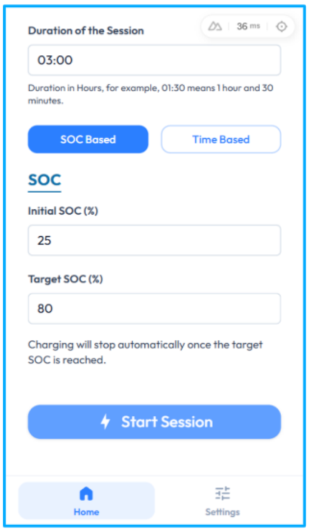
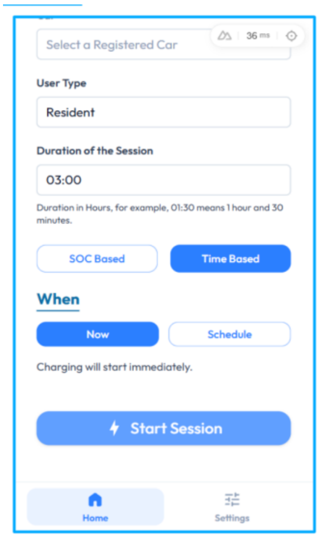
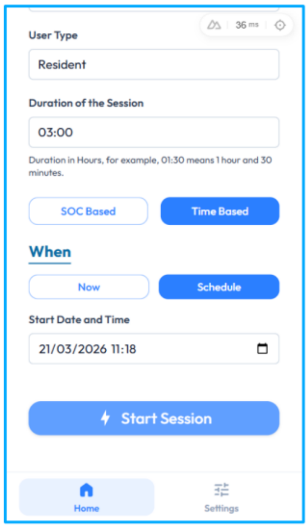


SMART CHARGING
SOC BASED CHARGING
(BOTTOM OF THE PAGE)

Smart Charging (SoC-based): The mobile application contains its smart charging setup interface instantaneously displayed on these screens. The top section allows users to define the main parameters of a charging session, including the selected charger, vehicle, user type, and session duration. It also provides options to choose between different charging strategies, such as SOC-based or time-based charging. The lower section provides information about SOC-based configuration, which enables users to enter their starting and ending SoC values. The system uses these inputs to control charging operations, which automatically end when the target SoC is achieved.

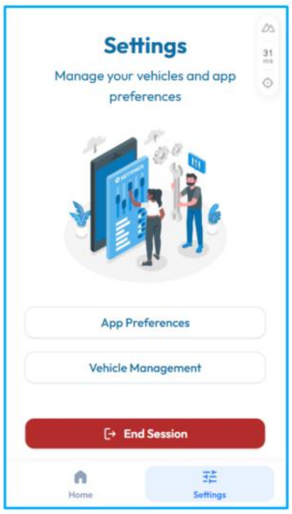


SMART CHARGING
TIME BASED CHARGING
(BOTTOM OF THE PAGE)

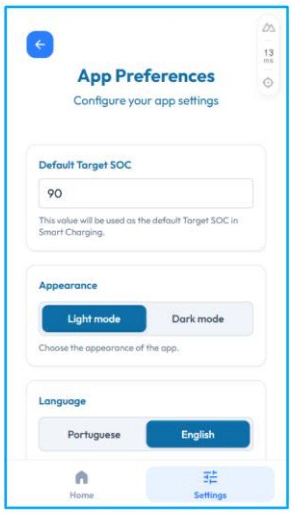


SMART CHARGING
TIME BASED CHARGING
(BOTTOM OF THE PAGE)

Smart Charging (Time-based): The mobile application displays its time-based smart charging system through these screens. Users can define their charging session length while selecting their preferred charging method between immediate execution and scheduled charging. The scheduling mode allows users to select their desired starting point for charging sessions which enables them to charge their devices according to their personal requirements, the requirements of external factors including energy costs, grid signals, and PV availability in their area. The application provides users with the ability to start a session after they finish their setup work.

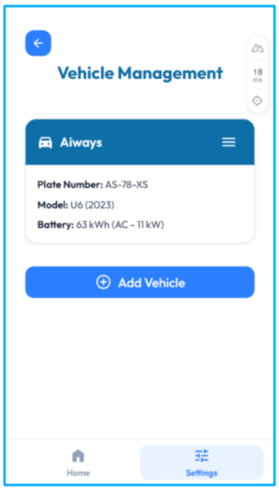


SETTINGS



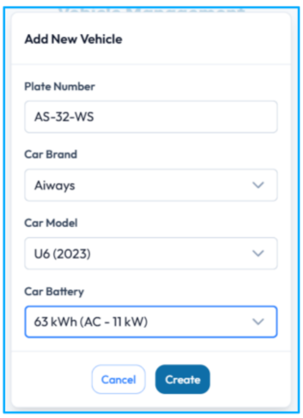
PREFERENCES

Setting Page: These screens present the application settings and user preference configuration functionalities. The settings screen provides access to key management options, including application preferences and vehicle management, as well as the ability to securely end the user session. The preferences screen allows end-users to customise the application behaviour according to their needs. This includes defining a default target SoC or smart charging sessions, selecting the visual appearance of the interface (light or dark mode), and choosing the application language. These configurable parameters enhance user experience and enable a more personalised and efficient interaction with the platform.

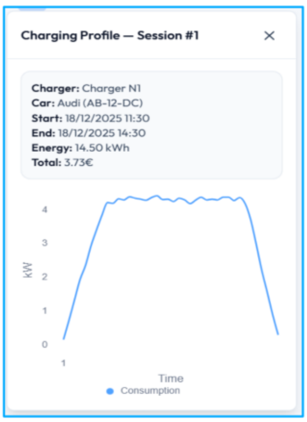


VEHICLE MANAGEMENT

Vehicle Management: This screen presents the vehicle management functionality of the mobile application. It provides an overview of the user's registered vehicles, showing key information EV battery specifications, which are essential for configuring charging sessions. The interface also allows users to add new vehicles to the system, ensuring flexibility in managing multiple assets.



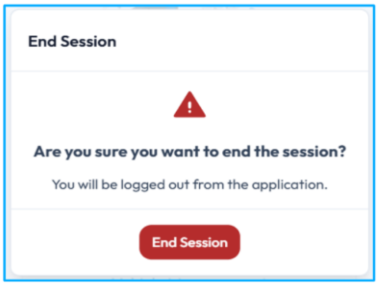
ADD VEHICLE



SESSION HISTORY PROFILE

Modals: The mobile application displays two features which allow users to check vehicle registration and perform detailed session analysis. The add vehicle screen allows users to register a new vehicle by providing key information such as license plate, brand, model, and battery specifications which enables accurate management of charging session setups. The session history profile screen provides a detailed view of a specific charging session which includes essential details about the charging session such as charger information and vehicle details and time of start and finish and energy used and total expenses. The system provides users with a visual display that shows how charging patterns developed throughout different time periods which allows users to examine their charging behaviour and performance.

STOP CHARGING SESSION



END SESSION

Termination: The screens display confirmation dialogs which appear when users perform essential functions throughout the mobile application. The stop charging session interface requires users to verify their decision before they can stop an active charging session which safeguards against unintentional charging session termination. The end session screen requires the user to confirm their logout request which shows the user what will happen after they proceed with the action. The two interfaces function as tools which provide users greater control over their actions while maintaining system stability because essential tasks must be performed with full user intent that protects against unexpected session drops and termination of their ongoing work.

4. CONCLUSIONS AND RECOMMENDATIONS

This deliverable presents complete details about how Western Europe Demonstrator systems were installed, commissioned, integrated and operated their various deployment locations which included public and semi-public and private charging facilities. The work carried out confirms the successful installation of the demonstrator in real-world conditions, covering heterogeneous use cases and operational contexts.

The document has detailed the full process from site preparation to system integration which includes charging infrastructure deployment, control system deployment, monitoring system deployment, and data management system deployment. The remote technical teams and on-site personnel created successful solutions for complex multi-component systems through their integrated coordination because it served as the main element which led to their successful integration. The implementation process needs continuous monitoring of regulatory and administrative frameworks because evolving requirements create new restrictions which affect both project timelines and technical decision-making. The process of spare parts management and equipment availability control in remote locations determines the delivery schedule therefore these aspects need to be organized before operational deployment starts. The findings demonstrate that implementation success requires technology design to match three elements which include system structure, operational methods and outside operational restrictions. The demonstrator experience provides valuable operational insights which show organizations how to handle their future system deployments through effective integration planning and risk prevention and operational management.

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