Ref. Ares(2025)10077215 - 20/11/2025

D6.3 – Electric Vehicles as active building element

This project has received funding from the European Union's Horizon Europe research and innovation programme under the grant agreement number 101147722. The European Union is not liable for any use that may be made of the information contained in this document, which is merely representing the authors' view.

Project Acronym:	AccesS
Project Full Title:	Enhancing Accessibility and Sustainability in Smart Cities and Smart Buildings: The Universal Accessibility Suite Initiative
Grant Agreement:	101147722
Project Duration:	36 months (01/06/2024 – 31/05/2027)

DELIVERABLE 6.3
Electric Vehicles as active building element

Work Package:	WP6 - Intelligent Systems for Adaptive Building and Mobility Management
Task:	T6.3 - Integrated e-Mobility: Electric Vehicles as active building element
Document Status:	Final
File Name:	AccesS_D6.3 Electric Vehicles as active building element_HIVE
Due Date:	30.11.2025
Submission Date:	20.11.2025
Lead Beneficiary:	HIVE

Dissemination Level	
Public	☒
Sensitive	☐

Authors List

Leading Author			
First Name	**Last Name**	**Beneficiary**	**Contact e-mail**
Laura	Casolo Ginelli	HIVE	laura.casologinelli@hivepower.tech

Co-Author(s)				
#	**First Name**	**Last Name**	**Beneficiary**	**Contact e-mail**
1	Panagiota	Chatzipanagiotidou	CERTH	phatzip@iti.gr
2	Napoleon	Bezas	CERTH	napobezas@gmail.com
3	Ioannis	Koskinas	CERTH	jkosk@iti.gr
4	Stefano	Mauri	AEM	smauri@aemsa.ch
5	Ilias	Aliferis	UNIS	aliferisI@unisystems.gr
6	Fabio	Garista	VAIMOO	fabio.garista@angel4future.com
7	Eva	Fernández Palacios	VOLTIVA	eva.fernandez@voltiva.energy

Reviewers List

Reviewers			
First Name	**Last Name**	**Beneficiary**	**Contact e-mail**
Ariadni	Elmaloglou	QUE	a.elmaloglou@que-tech.com
Raquel	Ortega Martínez	CETEM	r.ortega@cetem.es

Version History

v	Author	Date	Brief Description
0.1	Laura Casolo Ginelli, HIVE	21.07.2025	Table of content and deliverable structure
0.2	Laura Casolo Ginelli, HIVE	21.08.2025	First version with initial content for all sections
0.3	Panagiota Chatzipanagiotidou, Ioannis Koskinas, Napoleon Bezas, CERTH	26.08.2025	Updates in section 1 and pilot context
0.4	All authors	28.10.2025	Updated feedback in all sections
0.6	Ariadni Elmaloglou, Raquel Ortega Martínez	11.11.2025	Peer review
0.7	Laura Casolo Ginelli, HIVE	17.11.2025	Updated based on peer review comments
1.0	Laura Casolo Ginelli, HIVE Panagiota Chatzipanagiotidou, CERTH	20.11.2025	Final version ready for submission

Legal Disclaimer

The AccesS project has received funding from the European Union's Horizon Innovation Action under grant agreement No 101147722. The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the European Climate, Infrastructure and Environment Executive Agency (CINEA) or the European Commission (EC). CINEA or the EC are not responsible for any use that may be made of the information contained therein.

Copyright

© Hive Power SA, Via Cantonale 18, 6928 – Manno (CH). Copies of this publication – also of extracts thereof – may only be made with reference to the publisher.

Executive Summary

Electric vehicles (EVs) are rapidly becoming a cornerstone of the global transition toward sustainable mobility and energy systems. Beyond their role as transport solutions, EVs increasingly act as dynamic energy assets, capable of interacting with buildings and the electricity grid. This dual function transforms EVs into active building elements that both consume and potentially provide energy, thereby enabling new pathways for improving grid stability, energy efficiency, and user inclusiveness.

This report presents the design and development of the EV Charging Optimizer (as part of the AccesS Suite), a modular digital tool conceived to manage EV charging in a way that balances the needs of drivers, charging point operators (CPOs), and the local grid. The optimizer is based on predictive and optimization algorithms that align charging demand with grid capacity while safeguarding accessibility requirements. Its overarching goal is to provide a smarter, safer, and more inclusive charging process that contributes to the sustainable expansion of e-mobility charging infrastructures.

The Optimizer operates by retrieving and processing diverse data sources, including metadata from charging stations, historical usage records, and grid metering data. These inputs allow the system to identify operational constraints, and design optimal schedules that avoid peak overloads.

Importantly, accessibility is embedded as a core requirement: charging stations dedicated to elderly persons or people with disabilities are excluded from load-shifting, ensuring that their availability and responsiveness remain intact. Scalability is also addressed by incorporating indicators of infrastructure growth, enabling operators to anticipate how an increasing number of charging stations will impact their grid connection.

The results of the EV Charging Optimizer are made available through a user-oriented web interface that differentiates between EV drivers and Charging Point Operators (CPOs). For drivers, the interface provides simple, accessible information, helping them to better plan their charging and reduce waiting times. For operators, the dashboard offers advanced analytics, including power consumption histories, infrastructure scalability assessments, and the projected benefits of load-shifting strategies. Together, these views transform raw data into actionable insights that support both everyday decisions and long-term investment planning.

Although the system is designed around existing charging infrastructures, it also anticipates future developments in the e-mobility ecosystem. As bidirectional charging technologies (Vehicle-to-Grid, Vehicle-to-Building) become more widely available, the EV Charging Optimizer's architecture is prepared to integrate these capabilities, enabling EVs to act not only as flexible loads but also as distributed storage resources that can provide energy back to buildings or the grid. This represents a significant step toward a more resilient and interactive energy ecosystem, where EVs play a central role in balancing renewable generation and electricity demand.

Looking ahead, the deployment of the EV Charging Optimizer in real pilot sites will be essential for validating its effectiveness under operational conditions. The connection to live data streams from Charge Point Management Systems and grid metering infrastructures will allow further refinement of the tool. Moreover, site-specific conditions such as regulatory frameworks, technical constraints, and local accessibility requirements will be integrated into the system, ensuring that the Optimizer remains adaptable and context sensitive.

In summary, this work demonstrates how EV charging can evolve from a passive energy demand into an active component of sustainable energy management. These infrastructures are not only capable of serving the growing fleet of electric vehicles but also of supporting broader societal goals: reducing carbon emissions, enhancing grid resilience, and ensuring that all users, including those with special accessibility needs, can participate fully in the mobility and energy transitions.

Table of Contents

List of Figures

List of Acronyms and Abbreviations

Term	Description
AI	Artificial Intelligence
Bi-di	Bidirectional charging
CPMS	Charge Point Management System
CPO	Charge Point Operator
DER	Distributed Energy Resource
EDA	Exploratory Data Analysis
EV	Electric Vehicle
HTML	HyperText Markup Language
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
MILP	Mixed-Integer Linear Programming
OCPP	Open Charge Point Protocol
OAuth	Open Authorization
SSO	Single-Sign-On
UC	Use Case
V2B	Vehicle-to-Building
V2G	Vehicle-to-Grid
V2X	Vehicle-to-everything
WP	Work Package

1 Introduction

1.1 Scope and objectives of the deliverable

This report documents the activities and outcomes of *Task 6.3 – Integrated e-Mobility: Electric Vehicles as Active Building Elements*, within *WP6 – Intelligent Systems for Adaptive Building and Mobility Management*. In line with the WP6 objective of integrating e-mobility into building infrastructures, the task develops and validates predictive and optimisation algorithms to support grid-aware charging management, infrastructure scalability, and inclusive user interaction.

Electric vehicles are considered as dynamic components of the energy system, whose charging patterns significantly affect both building energy operation and local grid stability. Task 6.3 therefore addresses two main challenges: (i) the optimisation of charging schedules to mitigate peak demand and balance grid capacity, and (ii) the design of scalable infrastructures capable of accommodating future charging needs.

The methodological approach combines historical and real-time data from pilot sites to personalise charging behaviour and shift demand towards optimal periods. Special emphasis is placed on accessibility requirements, ensuring that the needs of elderly users and persons with disabilities are preserved within the optimisation process through priority allocation and predictive availability of accessible stations.

The developed tool, the EV Charging Optimizer, is evaluated across different algorithmic configurations to identify effective load-shifting strategies. Outcomes are made available through a web-based interface that supports both EV drivers and Charging Point Operators (CPOs): drivers are provided with transparent information on charging availability and station utilisation patterns, while operators gain insights into infrastructure performance, peak load dynamics, and future scalability requirements.

In this perspective, Task 6.3 contributes to the dual objective of improving the user experience and enabling a system-level view of e-mobility integration, thereby aligning individual charging behaviour with the operational needs of buildings and grids.

The deliverable's objectives are to (i) present the use case scenarios developed for the pilots, (ii) describe the solution architecture, including optimisation and accessibility features, (iii) provide an overview of the front-end functionalities for different user groups, (iv) outline future work for deployment, scalability and inclusiveness.

1.2 Structure of the deliverable

The present deliverable is organized into four main chapters, followed by the references section.

- **Chapter 1 – Introduction** provides an overview of the scope and objectives of the report, situating the work within the wider context of intelligent building and mobility management. It also explains the relationship of this deliverable to other outputs of the project.
- **Chapter 2 – Solution Architecture and Deployment** presents the conceptual and technical framework of the EV Charging Optimizer. It begins with a description of the use case and pilot site context, followed by the functional requirements and the overall system architecture. This chapter also details the design of the optimization algorithms, the procedure for integrating the tool into pilot sites, and the data required for its operation. The chapter concludes with an outline of the user interaction and visualization components, describing the differentiated interfaces for EV drivers and CPOs.

- **Chapter 3 – Outlook and conclusions** discuss the main findings and contributions of the deliverable for the future of e-mobility and energy systems. It highlights the increasing role of EV charging in the energy ecosystem, the opportunities arising from bi-directional and the refinements needed in data management during deployment phases. The chapter also explores scalability considerations and adaptation to further pilot sites.

1.3 Relation to Other Tasks and Deliverables

The work carried out in Task 6.3 is closely interconnected with several activities across the AccesS project, both within WP6 and in other work packages. These interdependencies ensure consistency of the developed solutions and enable the integration of the EV Charging Optimizer into the overall AccesS Suite.

- **WP1 – Foundations, Requirements and Architecture**

The requirements and framework architecture defined in WP1 provide the methodological and technical baseline for the developments in T6.3. The characterisation of pilot sites, the identification of user needs, and the accessibility principles established in WP1 are directly reflected in the optimisation features developed in this task.

- **WP2 – Social Inclusion and User-Centred Design Approach**

WP2 provides the roadmap for pilot sites by identifying user needs and accessibility challenges through stakeholder engagement. The findings from surveys, consultations, and barrier analyses guide the prioritisation of inclusive solutions and inform the development of tools, ensuring that technical outputs integrate social and accessibility considerations from the outset.

- **WP6 – Intelligent Systems for Adaptive Building and Mobility Management**

Within WP6, D6.3 complements the outputs of Task 6.1 (Building Operation and Management Systems) and Task 6.2 (Micromobility Planning). Together, these three tasks deliver the core set of intelligent tools that enable adaptive management of buildings and urban mobility. D6.3 contributes specifically by integrating e-mobility as an active building element, thereby completing the WP6 objective of demonstrating intelligent, data-driven solutions for adaptive and inclusive management.

- **WP7 – Integration into the AccesS Suite**

The algorithms, optimisation features, and user interfaces developed in T6.3 will be incorporated into the AccesS Suite and tested in WP7. This ensures full interoperability with other WP6 components and with the broader digital framework, enabling end-to-end integration across pilots and user groups.

- **WP9–12 – Pilot Preparation and Demonstrations**

The pilot sites serve both as testing grounds and as validation environments for the developed functionalities. Results from T6.3 directly feed into pilot deployment activities, supporting the evaluation of scalability, inclusiveness, and performance in diverse operational contexts.

Through these interrelations, D6.3 acts both as a standalone technical contribution and as a building block of the broader AccesS framework. It ensures that the integration of EVs as active building elements is aligned with architectural principles, accessibility objectives, and pilot deployment strategies, thereby maximising its impact across the project.

2 Solution architecture and deployment

2.1 System Architecture

Figure 1 displays the high-level architecture of the EV Charging Optimizer. The EV Charging Optimizer has been conceived as a modular system that integrates a diverse **set of input** data streams (in yellow) to perform optimization and accessibility-oriented scheduling. **Metadata from the charging stations** is retrieved via an Open Charge Point Protocol (OCPP) connection to the Charge Point Management System (CPMS) operated by the corresponding Charge Point Operator (CPO).

Together with historical records of station usage, this information serves as foundation for predicting charging demand and providing reliable availability insights to end-users. The integration of **metering data** from the grid connection point, in combination with the **maximum power** constraint at the chargers' connection node, enables the Optimizer to align charging schedules with local grid requirements, thereby reducing peak loads and mitigating potential congestion issues.

A further component addresses the scalability of charging infrastructures. By introducing a **growth indicator** reflecting the anticipated increase in the number of charging stations, the Optimizer can assess future infrastructure limitations and propose expansion pathways that minimize costly grid reinforcements while maintaining a seamless charging experience.

Accessibility requirements are also embedded as a structural input. The CPO can define which charging stations are reserved for persons with disabilities or elderly users. These stations are excluded from load-shifting measures, ensuring that priority users benefit from consistently higher availability and reduced charging times, thereby safeguarding inclusiveness in energy management.

Within the system architecture, this input information forms the basis for several **algorithmic modules** that constitute the computational core of the Optimizer (in blue). These modules cover the acquisition and pre-processing of data, the identification of operational and infrastructural constraints and the execution of optimization routines.

The specific functionalities of the modules are presented in the next chapter of this deliverable.

The results are delivered as **output** elements (in green) via a web-based interface that differentiates between end-user groups.

For EV drivers, the interface provides accessible information on expected station utilization patterns, including a "Popular Charging Times" feature displaying average availability profiles throughout the week. For CPOs, a more advanced set of analytics is made available, comprising detailed station usage statistics, historical power consumption records, and infrastructure scalability assessments. This functionality allows operators to evaluate system performance, anticipate grid impacts, and support investment planning in view of the rapid diffusion of e-mobility.

Overall, the Optimizer constitutes an integrated solution that addresses the requirements of drivers, operators, and grid operators alike. By embedding scalability considerations and accessibility requirements within a unified framework, the system enhances the efficiency, inclusiveness, and sustainability of EV charging infrastructures, fully aligning with the objectives of Task 6.3.

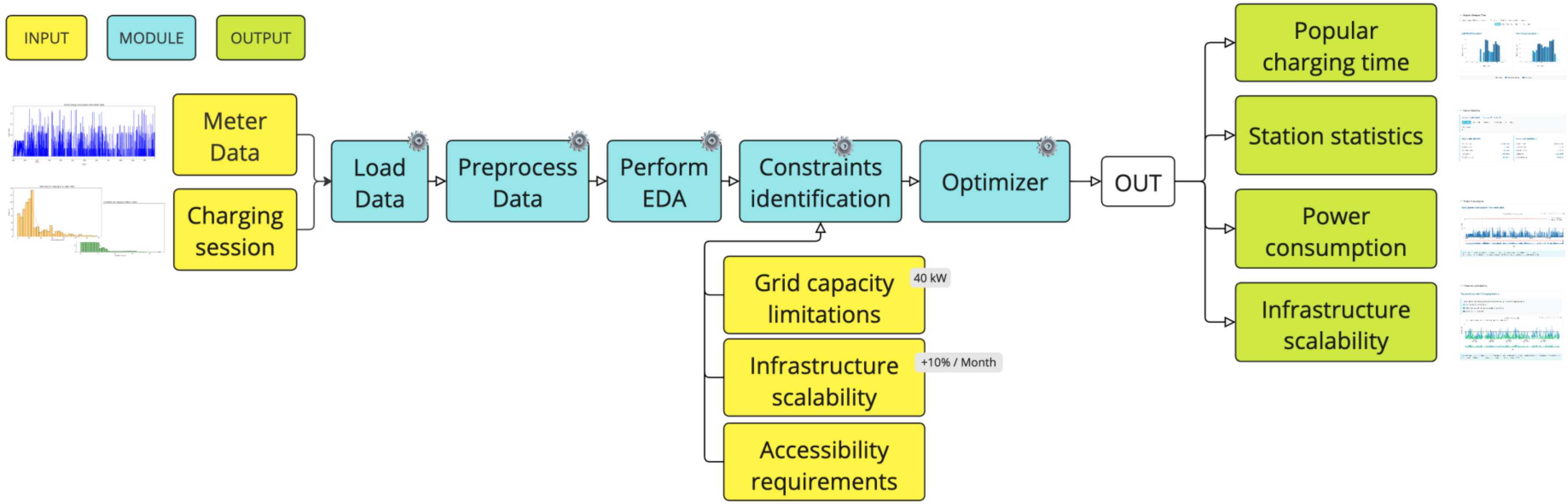

Figure 1 EV Charging Optimizer high level architecture

2.2 Algorithm design

The EV Charging Optimizer has been designed as a **modular architecture** that ensures scalability, interoperability, and clear separation of functions. Its primary purpose is to enable optimization and monitoring of EV charging activities, while maintaining compliance with grid capacity constraints and addressing accessibility requirements.

Python was selected as the programming language for the EV Charging Optimizer because of its strong data science and modelling capabilities. Existing libraries, such as Prophet and pulp, support time-series analysis, numerical computation and linear programming. Its clean syntax and modular design make the system easy to maintain and extend.

The system is composed of several modules, each responsible for a distinct function within the data pipeline, ranging from ingestion and cleaning of raw data to advanced analytics, optimization and evaluation. The modular design ensures that each component can be individually maintained, updated, or replaced, without compromising the integrity of the overall system.

The EV Charging Optimizer operates on a **daily execution** schedule, as real-time or finer time granularity is not required for the targeted use cases.

The **different modules** are described below in detail.

Loader and Preprocessor

The processing pipeline begins with data ingestion and preparation, through the *Loader* and *Preprocessor* modules, which standardize raw inputs such as meter readings and charging session records. These modules clean, transform and prepare raw data for analysis and optimization, performing key operations such as timestamp conversion, duplicated removal and handling of missing data.

Analyzer

Once prepared, the data is processes by the *Analyzer*, which performs Exploratory Data Analysis (EDA) and generates insights into energy consumption, charging behaviour, and accessibility-related usage patterns.

Constraint identifier

These insights are subsequently processed by the Constraint Identifier, which detects grid capacity limitations and simulate future scalability scenarios. Power consumption is monitored at a 15-minute resolution, enabling the identification of potential violations against the predefined grid capacity threshold.

To assess long-term scalability, the module simulates the growth of charging stations using compound growth models, projecting the corresponding increase in charging demand. The projected load is then re-evaluated against the grid capacity, and, whenever the limits are exceeded, the Optimizer is triggered to apply load-shifting strategies, thereby redistributing charging demand and ensuring compliance with grid constraints. The purpose of this simulation is to test whether load shifting can prevent grid overload under scenarios involving the addition of new charging stations.

Optimizer

The optimization core is managed by the Optimizer module, which employs mathematical programming techniques to reallocate charging sessions with the objective of reducing peak loads while simultaneously respecting user preferences and accessibility constraints.

Each charging session may be shifted within a flexibility window of ±2 hours, in 15-minute increments, and the objective function is formulated to minimize the maximum total power consumption across all intervals.

Sessions associated with accessibility-flagged users are excluded from any shifting, thereby ensuring full compliance with accessibility requirements.

In the optimisation model, each charging session is characterised by a start decision and an active state. The system decides when to start each session within its allowed flexibility window and tracks the resulting charging period accordingly. This ensures that the grid constraints are respected and peak load reduction is pursued.

A maximum computational time of 300 seconds is imposed on the solver; if no fully feasible solution is obtained within this limit, the best partial solution available is returned to guarantee continuity of operation.

The optimization problem can be expressed in the following mathematical form.

Decision Variables

- $x_{i,t} \in \{0,1\}$: start decision - binary variable equal to 1 if charging session i starts at time slot t, 0 otherwise
- $y_{i,t} \in \{0,1\}$: active indicator - binary variable equal to 1 if charging session i is charging at time slot t

Parameters

- P_i: charging power of session i
- C: maximum grid capacity of the site
- T_i: duration (in slots) of session i
- W_i: flexibility window of session i ($\pm 2h$)

Constraints

- **Unique Start time**: each charging session must be scheduled once.

$$\sum_t x_{i,t} = 1 \ \forall i$$

- **Flexibility window**: charging sessions can only start within their allowed flexibility window.

$$x_{i,t} = 0 \ if \ t \ \notin W_i$$

- **Grid capacity**: the aggregate power at each time slot must not exceed the grid connection limit

$$\sum_i P_i \ y_{i,t} \ \leq C \ \forall t$$

- **Accessibility constraint**: if session i is accessibility-flagged (so it can not be shifted), then $x_{i,t}$ is fixed to the original start time.

Objective function

The objective is to minimize the maximum total load across all the time slots, flattening the demand curve.

$$\min \max_t \ (\sum_t P_i \ y_{i,t})$$

Given this mathematical optimization problem, three different solution strategies for the scheduling of electric vehicle charging sessions have been evaluated:

- **Mixed-Integer Linear Programming (MILP)**
- **Greedy Heuristics**
- **Genetic Algorithms (GAs)**

Mixed-Integer Linear Programming (MILP) encodes this formulation directly into a set of linear equations and inequalities, enabling solvers to produce globally balanced schedules that guarantee adherence to all constraints. This approach has been widely applied in smart charging and demand response contexts, offering provable optimality and transparency of results. [2] [3]

In contrast, **Greedy Heuristics** implement the same rules sequentially, typically prioritising larger or earlier sessions and assigning them to the first feasible slot. While this method is computationally efficient and suitable for near-real-time approximations, it lacks the capacity to assess the global impact of local decisions and may therefore, result in residual demand peaks. [4]

A third class of methods, **Genetic Algorithms (GAs)**, reformulates the optimisation problem into a fitness-based search, where candidate schedules evolve iteratively through processes of selection, crossover, and mutation. While GAs have demonstrated achieve competitive performance in EV charging and microgrid applications [5] [6], they require careful parameter tuning and generally lack the predictability and constraint enforcement strength of MILP approaches.

For the purposes of this deliverable, where grid capacity limits and accessibility requirements are non-negotiable, MILP emerges as the most reliable solution, while heuristic and evolutionary approaches may be retained as complementary methods for rapid estimation or exploratory analysis.

The optimizer's main operational objective is to reduce the maximum aggregated charging power at the site. The reduction is quantified by comparing the uncontrolled peak load with the optimized one.

$$Peak - load\ reduction\ (\%) = \frac{P_{max,uncontrolled} - P_{max,optimized}}{P_{max,uncontrolled}} x\ 10$$

This Key Performance Indicator (KPI) expresses how effectively the scheduling algorithm flattens the demand curve, thereby reducing grid stress and supporting local energy stability.

Data Converter

Finally, the Data Converter transforms processed data into lightweight, web-compatible JSON formats, enabling seamless dashboard integration and user interaction.

Output dashboard

The system is implemented as self-contained HTML-based visualization dashboards that are designed to be maintainable, secure, and user-friendly while managing complex data visualizations. The front-end architecture is structured around a header component, a tab-based navigation system, and dedicated plot containers. The tab-based navigation system allows to switch between the EV driver and CPOs view.

HTML was chosen for the dashboards because it provides universal accessibility across all devices and browsers without requiring users to install any additional software, while offering rich interactive capabilities through JavaScript libraries. All interactive charts are implemented with Plotly.js, which provides dynamic visualization capabilities and allows users to customize the displayed time ranges.

Access to the dashboard is managed through the AccesS Suite, with authentication handled via Keycloak integration. This provides enterprise-grade authentication and single sign-on (SSO), ensuring secure access to sensitive charging infrastructure data. As an open-source identity and access management solution, Keycloak oversees authentication, authorization, and session handling using industry-standard protocols such as OAuth 2.0 and OpenID Connect, thereby removing the need to develop custom security mechanisms.

2.3 Deployment and integration

The EV Charging Optimizer developed in Task 6.3 is conceived as a component of the broader **AccesS Suite**, which serves as the **central digital platform** of the project.

The Suite has been designed as a unified, modular, and customizable framework that integrates the diverse software tools, services, and functionalities emerging from the different work packages, thereby ensuring coherence, interoperability, and accessibility across the entire ecosystem. Through its layered architecture, the AccesS Suite connects data processing and analytical modules with representation and information management services, offering a seamless interface between technical tools and end users.

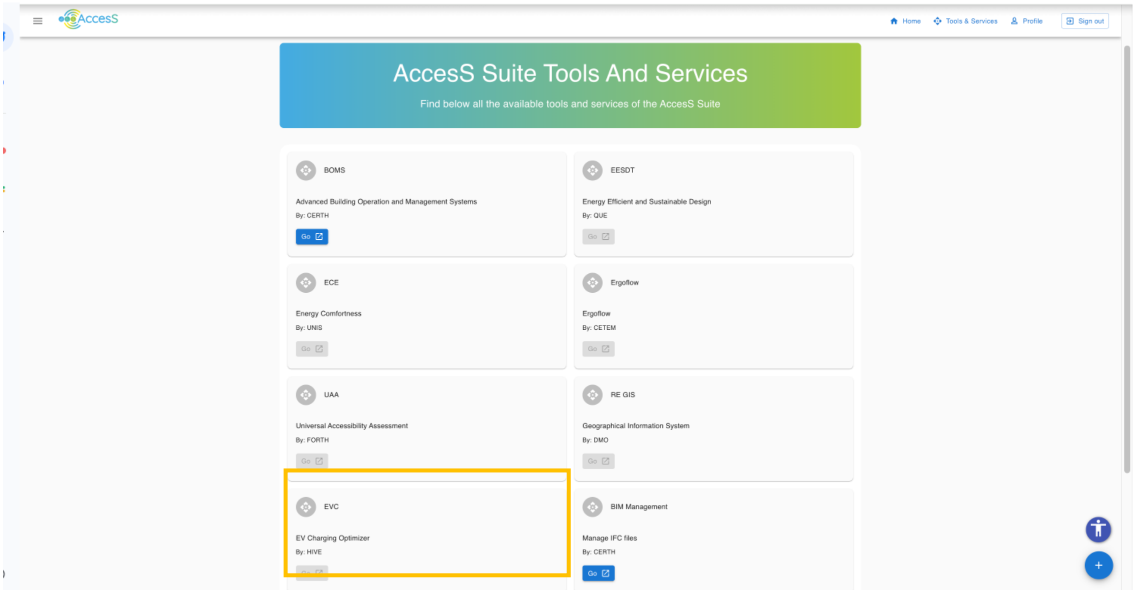

Figure 2 AccesS Suite central digital platform

A strong emphasis is placed on inclusiveness and accessibility, enabling the platform to address the requirements of older persons and people with disabilities, while maintaining compatibility with heterogeneous infrastructures, devices, and communication protocols.

A central web server underpins the user-facing interface, providing access to KPIs, recommendations, and accessibility reports, while the **Keycloak authentication layer** ensures enterprise-grade security, role-based permissions, and SSO capabilities.

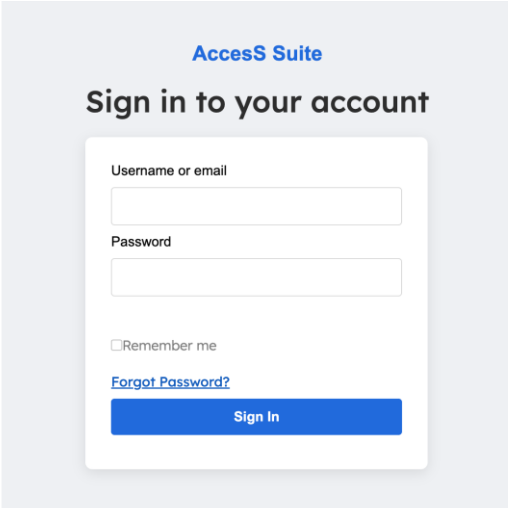

Figure 3 AccesS Suite Sign-in page with Keycloak

Each pilot site manager is granted comprehensive access to the full dataset and operational details of their respective pilot site, while EV drivers are provided with a restricted interface that only allows them to view publicly available statistics and general charging information, ensuring transparency while safeguarding sensitive pilot data.

Accessible within this environment (see yellow box in Figure 2), the EV Charging Optimizer contributes by delivering predictive and optimization functionalities for electric vehicle integration, while benefiting from interoperability with other AccesS tools in domains such as adaptive building management, micromobility, and accessibility certification.

In this way, the AccesS Suite operates both as a gateway for differentiated user groups, including EV drivers, CPOs, and planners, and as a unifying framework for validating and scaling the project's innovations.

Ultimately, it represents the cornerstone of the project's ambition to deliver a comprehensive AI-driven Universal Accessibility Suite, aligning technological innovation with inclusiveness, security, and operational robustness.

The deployment of the EV Charging Optimizer in the pilot sites requires the following steps:

- **Charging infrastructure setup**: Charging stations must be installed and connected to a Charge Point Management System (CPMS).
- **Data access**: The pilot owner ensures access to the CPMS and grants Hive Power permission to retrieve metadata on charging sessions.
- **Historical data availability**: The availability of historical charging data is preferred, as it allows accurate model training. In the absence of such data, the system can start collecting new records and progressively improve model accuracy over time.
- **Grid data integration**: Metering data from the grid connection point are required, with access provided by the pilot owner, to align optimization with grid constraints.
- **System configuration:** Key parameters such as the maximum allowable grid power and the assumed infrastructure growth rate must be configured to ensure correct optimization and scalability simulations.
- **Tool activation**: Once all data streams are connected, the tool becomes operational, and visualizations are made available through the AccesS Suite.
- **User registration and roles**: Users register within the AccesS Suite, with role-based access control determining which information is visible on the platform (e.g. EV driver, operator).

- **System updates**: The web interface is refreshed daily, ensuring that optimization results remain consistently up to date.

The deployment of the EV Charging Optimizer will be carried out as part of WP9 and WP10-WP12 activities. Specifically, WP9 (Pilots preparation and set-up) covers the installation of the infrastructure, the provision of connectivity, and the training of stakeholders for the use of the AccesS Suite. The subsequent WP10, WP11, and WP12 are devoted to the deployment, validation, and impact assessment of the system in pilots' environments.

The EV Charging Optimizer developed in Task 6.3 will be integrated into the AccesS Suite and tested in a controlled environment before actual deployment as part of Tasks T7.2 & T7.3 respectively.

The work carried out in WP6 provides the conceptual and technical foundation, while WP7 allows the integration in an inclusive Suite and testing and WP9–WP12 ensure the operational implementation and validation in real pilot environments.

2.4 User interaction and visualization

The EV Charging Optimizer's dedicated user interface allows the users to interact with the system's outputs. In line with the project's accessibility and inclusiveness principles, the design of the web application is based on a role-based visualization approach, ensuring that different categories of users are provided with relevant information at an appropriate level of detail.

This chapter illustrates a concrete example of how the front-end of the EV Charging Optimizer would appear to end users, using data and results derived from the historical records provided by the Casa Girasole pilot site in Massagno, Switzerland. The purpose of this example is to demonstrate the way in which raw charging and metering data, once processed and analysed, are transformed into intuitive visualizations and user-oriented insights.

By simulating actual usage patterns, the example highlights how the interface supports both EV drivers and CPOs in understanding charging dynamics, forecasting availability, and evaluating infrastructure performance.

Two primary user profiles have been defined i.e. EV Drivers and Charging Point Operators:

- **EV Drivers**

The EV driver interface is designed to be intuitive, lightweight, and supportive of everyday charging decisions. It provides visibility charging demand trends, helping users to plan their charging activities more effectively.

A key feature is the "popular charging times" section (Figure 4), which visualizes typical station usage patterns throughout the day and across the week, allowing drivers to identify periods of lower demand and optimize their charging behavior accordingly.

For accessibility purposes, information about dedicated charging stations for elderly or disabled users is clearly highlighted, and these priority stations are excluded from load-shifting optimization, ensuring that they remain consistently available and unaffected by scheduling adjustments.

By presenting data in a simplified and user-friendly format, the driver view enhances confidence in charging availability, helps minimize waiting times, and contributes to a more streamlined and inclusive charging experience.

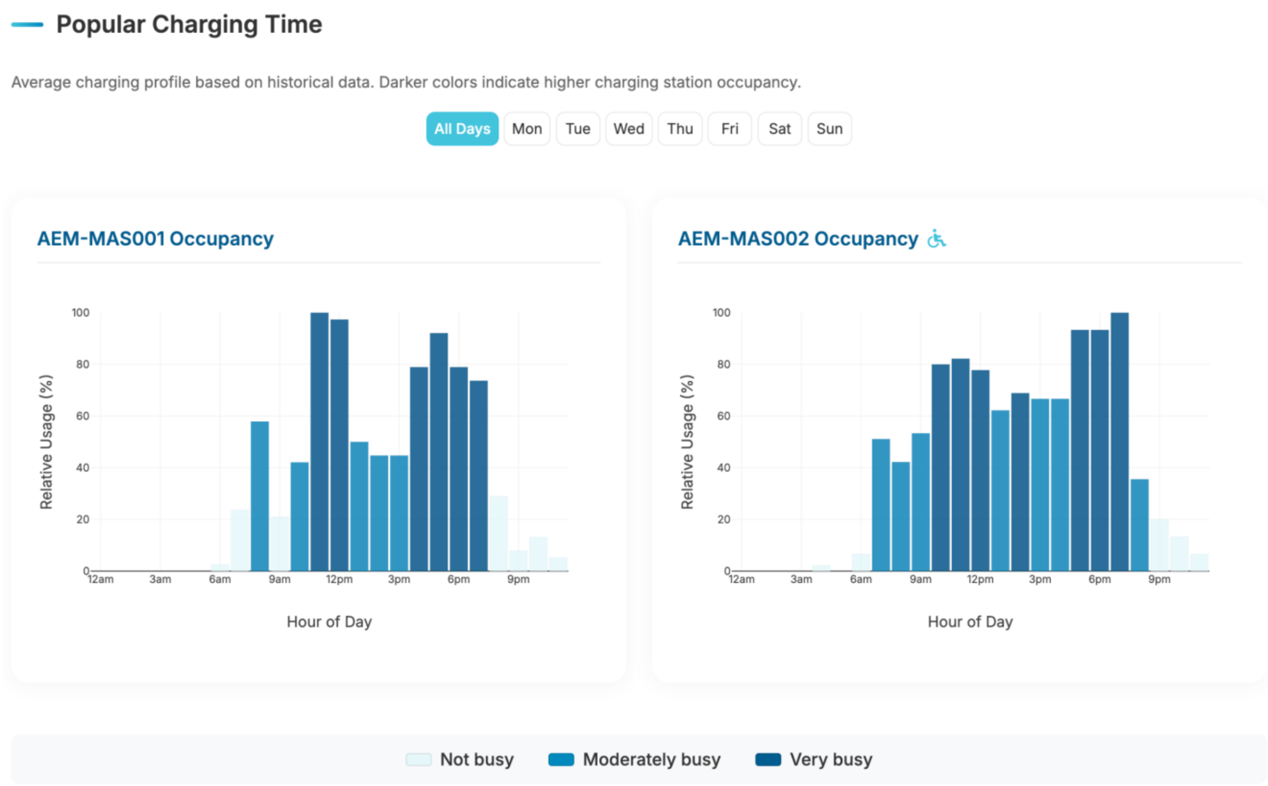

Figure 4 Popular charging time widget

- **Charging Point Operator (CPO)**

The Charging Point Operator (CPO) view provides a more advanced and data-intensive interface, reflecting the operator's responsibilities in both day-to-day infrastructure management and long-term strategic planning. This dashboard (in Figure 5) consolidates comprehensive analytics on charging station performance, enabling operators to assess key indicators such as average and maximum power levels, total energy consumption over a selected timeframe, and average charging session duration. The interface allows users to select different time horizons (monthly, weekly, or custom ranges), offering flexibility in monitoring patterns and adapting the analysis to specific operational needs. The same framework is designed to seamlessly accommodate the integration of additional charging stations when available.

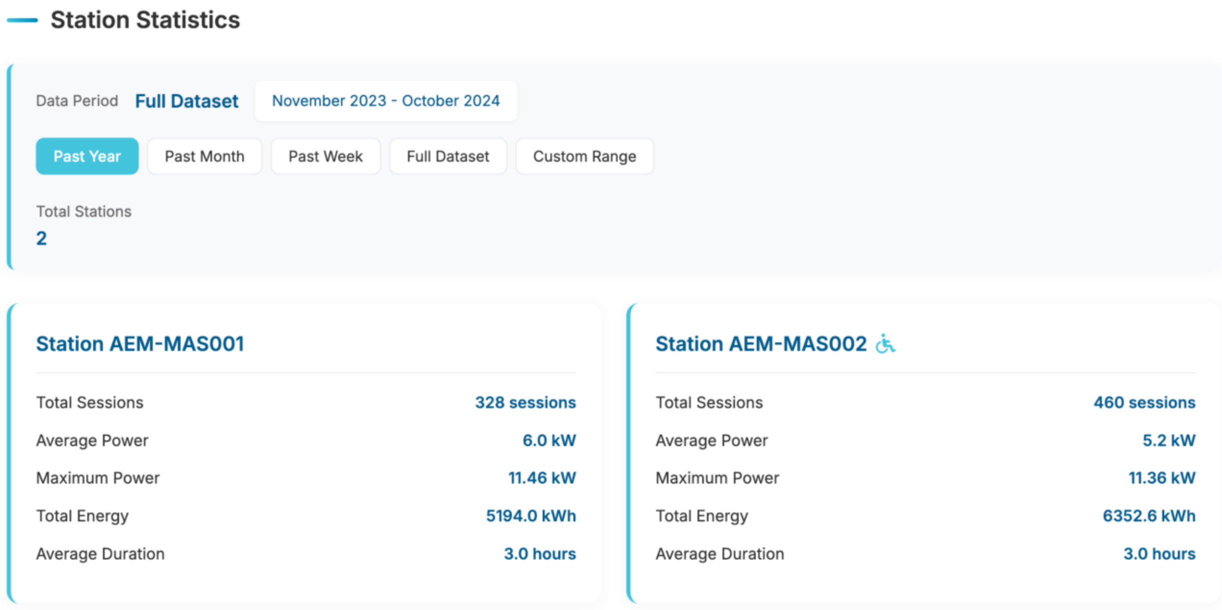

Figure 5 Station Statistics widget

By retrieving data directly from the metering system at the grid connection point, the CPO dashboard enables operators to visualize the historical power consumption profile (Figure 6) and compare it against predefined grid capacity thresholds (e.g., a 40kW limit in the present case).

This functionality provides immediate insight into whether and when consumption approaches or exceeds operational boundaries, thereby supporting informed decisions on load management and infrastructure planning.

The dashboard further enhances usability through interactive navigation tools: users can zoom into specific periods of interest by dragging the selection bar and dynamically adjusting the visible time range. This interactivity ensures that both high-level trends and fine-grained consumption details can be analysed within the same interface, offering flexibility to operators who must balance long-term monitoring with short-term operational oversight.

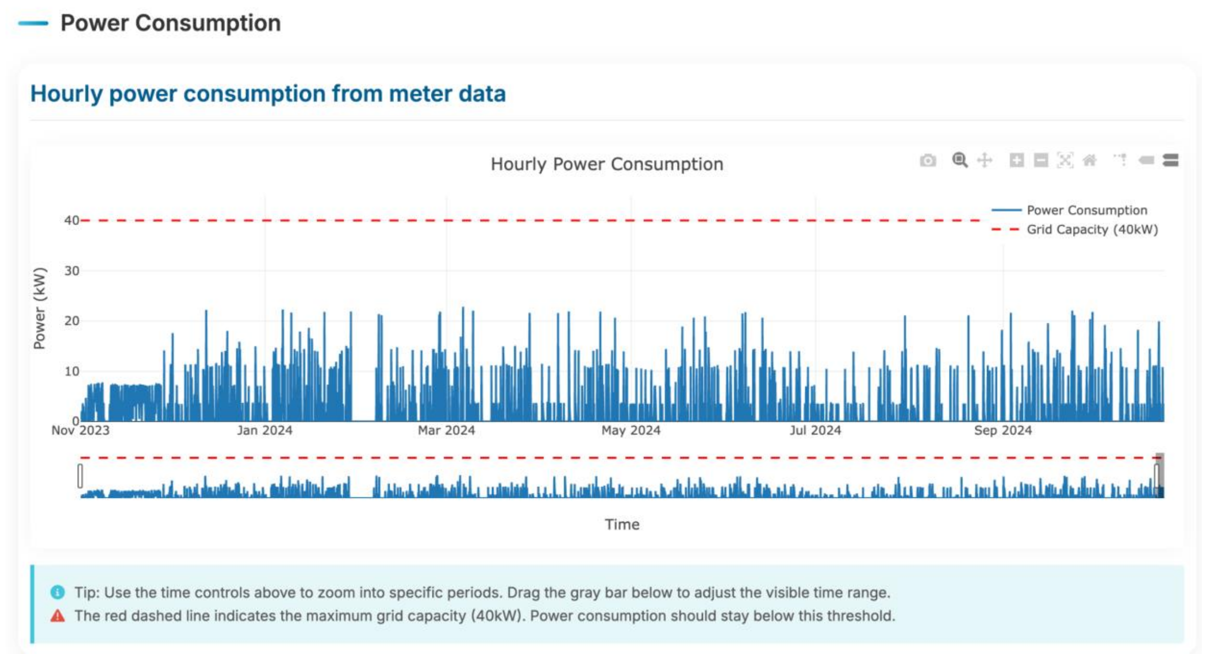

Figure 6 Power consumption widget

In addition, the EV Charging Optimizer provides infrastructure scalability assessments (Figure 7), simulating the impact of adding new charging stations to assess grid capacity under alternative growth scenarios. These insights allow operators to anticipate potential grid constraints and evaluate whether infrastructure reinforcements may be required. The CPO dashboard simultaneously displays uncoordinated demand and optimized load profile, highlighting the effectiveness of load-shifting measures in mitigating grid stress. Furthermore, the analysis supports both short-term operational decisions and long-term planning for charging-infrastructure development.

Furthermore, the analysis demonstrates how these benefits can be further enhanced through the integration of local load management solutions (e.g. power modulation or dynamic load balancing), which can absorb residual overloads that persist beyond what optimization alone can achieve.

In this way, the EV Charging Optimizer provides operators with an integrated decision-support instrument that combines historical analysis, real-time insights, and strategic foresight for investment planning and long-term infrastructure development.

Figure 7 Infrastructure Scalability widget

2.5 Use case and pilot context

As described in D1.2 [1] the development of the EV Charging Optimizer in Task 6.3 is grounded on two principal use cases that frame the integration of electric vehicles into building infrastructures and their role as flexible energy resources.

- *UC6.1 – Optimization of EV Charging in Building Infrastructure*

This use case focuses on managing load distribution across charging stations, avoiding congestion during peak demand periods, and improving energy efficiency. By leveraging predictive algorithms, charging demand can be dynamically shifted to off-peak hours, reducing stress on local grids and lowering energy costs. Accessibility criteria are embedded into this process, ensuring that the needs of elderly users and persons with disabilities are explicitly preserved when charging schedules are adjusted, for example by reserving one or more charging stations for users with accessibility needs. These resources always remain available and are excluded from any load-management actions, ensuring equitable access without requiring user-specific identification or authentication.

- *UC6.2 – Enabling EVs as Distributed Energy Resources (DERs)*

This use case considers bidirectional charging (V2B/V2G), whereby EVs provide flexibility to buildings and contribute to grid stability. By temporarily discharging into the building or the grid, EVs can mitigate peaks, reduce operating costs, and improve the overall resilience of the energy system.

Accessibility considerations remain integrated, ensuring that priority users are not disadvantaged by flexibility operations.

It is important to note that, from a technical standpoint, bidirectional charging operation requires compatible charging hardware (DC or AC V2X-capable chargers), V2X-capable vehicles and dedicated communication protocols (such as ISO 15118-20), which are not yet widely commercially deployed in Europe. On the regulatory side, grid connection rules, metering requirements, and remuneration schemes for energy fed back to the grid remain heterogeneous across EU countries, limiting large-scale implementation for now.

These use cases are analysed within the project's pilot environments, highlighting possible opportunities for testing and deployment.

EV Charging Optimizer functional requirements

For applying the EV Charging Optimizer, a set of technical and functional requirements must be fulfilled. First, the site must be equipped with an operational charging infrastructure capable of providing reliable data on charging sessions, power demand, and station occupancy. This infrastructure should be integrated with a Charge Point Management System (CPMS) to enable real-time monitoring and, where possible, control. The CPMS should be under the responsibility of the pilot site owner, ensuring proper data governance and system management.

In addition, access to grid-level information such as metering data and capacity constraints is essential to enable optimisation within realistic system boundaries. Equally important is the inclusion of information on charging stations reserved for elderly and disabled users, so that accessibility requirements can be explicitly embedded in the scheduling and prioritisation logic.

Where applicable in terms of V2G-ready infrastructure and vehicles, pilots may also support bidirectional (V2X) functionalities, allowing electric vehicles to provide flexibility services back to the building or the grid. Validation with the use of synthetic or simulated data to replicate relevant operational conditions will also be considered, or the utilisation of data from CERTH/ITI nZEB Smart House that acts as a testing environment for the project within T7.3 and where bidirectional charging infrastructure is already in place.

With respect to these technical and functional requirements, the analysis reveals a heterogeneous level of maturity of EV charging infrastructure across the AccesS demonstrators at this point.

In particular, Gabrovo, Florence, Bari, and Murcia are not equipped with suitable charging infrastructure or currently lack ownership and management control over the charging stations.

Naaldwijk and Massagno represent more advanced contexts. **In Naaldwijk**, the procurement process for the charging infrastructure has already been initiated, with a vendor selected and the evaluation of control back-end options currently ongoing to enable CPMS integration. The site can be considered for testing once the new uni-directional or bi-directional charging stations are installed in the near future (UC 6.1 or UC 6.2).

In Massagno, the pilot site already features operational charging stations suitable for the demonstration of uni-directional charging scenarios, providing a ready environment for implementing and validating the use case (UC 6.1).

These two pilots therefore offer concrete opportunities to validate optimisation and accessibility features, providing valuable feedback and insights for the future application in the other AccesS pilot sites and ensuring relevance for both current and future e-mobility scenarios.

This diversity of contexts is highly beneficial, as it enables the project to identify both the prerequisites for deploying optimisation tools and the pathways for scaling them across diverse urban and building environments.

Figure 8 EV Charging stations installed in Massagno, Switzerland

3 Outlook and conclusions

The work carried out in Task 6.3 has demonstrated the potential of the EV Charging Optimizer to serve as a bridge between electric mobility and intelligent energy management. By embedding optimization functionalities into the AccesS Suite, the system establishes a foundation for inclusive, data-driven charging coordination that addresses both user needs and grid stability.

Looking ahead, several opportunities emerge for refinement and further deployment. A key area of development concerns the integration of Vehicle-to-Everything (V2X) services, which will become increasingly relevant as bi-directional charging capabilities become more widespread among chargers and vehicles. This evolution would extend the Optimizer's scope from managing unidirectional demand to orchestrating two-way energy flows, enabling EVs to function as distributed storage assets that actively support grid balancing and renewable energy integration.

In parallel, the forthcoming pilot activities under WP10–WP12 will involve the integration of live data streams from CPMS and metering infrastructures, ensuring that the optimizer operates on validated, real-time information.

This phase will also enable the incorporation of additional site-specific parameters, such as regulatory conditions, grid constraints, or accessibility provisions, which can not yet be fully anticipated at this stage.

Taken together, these advancements point to a broader transformation: as electric vehicles become more deeply embedded in energy infrastructures, EV charging is poised to assume a central role in the energy ecosystem. The optimizer presented here not only demonstrates how this integration can be achieved today but also lays the groundwork for a future in which EV charging contributes decisively to a more adaptive, resilient, and user-centred energy system.

4 References

[1] «D1.2 AccesS Framework architecture, use cases and master planning for demonstrators».

[2] D. C. G. L. &. Z. Y. Aliprantis, «Coordination of electric vehicle charging for optimal distribution system management,» *IEEE Transactions on Power Systems*, 2017.

[3] E. &. E.-S. M. Sortomme, «Optimal charging strategies for unidirectional vehicle-to-grid,» *IEEE Transactions on Smart Grid,* 2011.

[4] D. B. F. D. &. K. A. Richardson, «Local versus centralized charging strategies for electric vehicles in low voltage distribution systems,» *IEEE Transactions on Smart Grid,* 2012.

[5] A. F. H. E. &. E.-S. Mohamed, «Coordinated charging of plug-in hybrid electric vehicles in smart distribution systems,» *IEEE Transactions on Smart Grid*, 2019.

[6] K. M. M. Z. A. A. P. B. &. T. C. Knezović, «Supporting involvement of electric vehicles in distribution grid operation: Ensuring benefits for both EV owners and distribution system operators,» Energy, 2017.

Enhancing Accessibility and Sustainability in Smart Cities and Smart Buildings: The Universal Accessibility Suite Initiative

www.euproject-access.eu/en/

@EU project AccesS

@EUprojectAccesS

@EUprojectAccesS

This project has received funding from the European Union's Horizon Europe research and innovation programme under the grant agreement number 101147722. The European Union is not liable for any use that may be made of the information contained in this document, which is merely representing the authors' view.