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Deliverable D9.1 Use case specification, development, installation, commissioning, demonstration, and evaluation planning for the Danish demo

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Electric Vehicles Management for carbon neutrality in Europe

Deliverable D9.1
Use case specification, development, installation, commissioning, demonstration, and evaluation planning for the Danish demo

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Disclaimer

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[1] https://ev4eu.eu/

Executive Summary

This deliverable consolidates the final specifications for the Use Cases (UCs) to be demonstrated in Denmark. The deployment plan includes an initial assessment of the current infrastructure at both locations, i.e., Risø and Campus Bornholm. Risø is a research campus of the Technical University of Denmark (DTU) and located in Roskilde, while Campus Bornholm is an educational institute in the main town Rønne on the island of Bornholm. Based on the assessment of both locations, the present document presents a detailed description of hardware and software that will be implemented, and the associated construction works required for their deployment.

The Electric Vehicle (EV) charging infrastructure is identical at both locations and comprises six Alternating Current (AC) chargers (22 kW), respectively. Each of the six AC chargers has two outlets, providing the opportunity for twelve EVs to be connected at the same time. The charging infrastructure is integrated via a 43 kW grid connection, and operated through a load management system enabling the maintenance of aggregated consumption below a specified threshold. This offers various benefits, e.g., preventing component overloading or the provision of both local and external services, such as peak shaving, increasing self-sufficiency, and frequency control.

Each charger deployed in this project is equipped with a controller that enables the charger to make autonomous control decisions. This facilitates distributed control schemes where all chargers are provided with global quantities, such as the cluster reference power and the actual cluster consumption, based on which all chargers individually control their respective charging session to collectively meet the cluster requirements.

Users of the charging infrastructure will start their charging sessions through an app, which is developed as part of the EV4EU project. The app allows the user to provide key inputs, such as the anticipated parking time and the required energy, which enable the load management system to consider user preferences while controlling the overall cluster consumption. The data acquisition and logging further include high-resolution power measurements at each charger, and of the overall cluster consumption through a dedicated meter at the point of common coupling (PCC).

Moreover, the deliverable proposes 19 Key Performance Indicators (KPIs) for quantifying the performance and impact of the demonstration activities. The KPIs are organized in four main categories, addressing economic, technical, user-related, and environmental impacts. Finally, the document summarizes the current status of the infrastructure deployment and gives an outlook for the upcoming tasks within the Danish demonstration. Specifically, Task 9.2 will finalize the already well-advanced deployment and commissioning of the charging infrastructure at both locations, followed by the start-up of operation.

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Acronyms

AC	Alternating current
AWS	Amazon Web Services
BB	Beaglebone
BUC	Business Use Case
CA	Cloud Aggregator
CO2	Carbon Dioxide
DTU	Technical University of Denmark
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
ID	Identification
KPI	Key Performance Indicator
PCC	Point of Common Coupling
PV	Photovoltaics
QR	Quick Response
UC	Use Case
V2X	Vehicle to Everything
VA	Virtual Aggregator
WB	Whiteboard

1 Introduction

1.1 Scope and Objectives

The integration of electric vehicle (EV) chargers into various buildings, particularly public structures like educational facilities, public administration buildings, and office spaces, is anticipated to become increasingly prevalent in the near future. As this trend gains momentum, the role of smart charging becomes pivotal, particularly in instances where local Photovoltaic (PV) or wind energy generation is accessible. The symbiotic relationship between EV chargers and renewable energy sources presents a unique opportunity to optimize energy management strategies, contributing to sustainability goals and enhancing the efficiency of the overall energy system.

Exploring the advantages of incorporating Vehicle-to-Everything (V2X) strategies in the energy management of parking lots assumes significance. The dynamic nature of V2X technologies allows for a comprehensive and bidirectional flow of energy between Electric Vehicles (EVs) and the grid, encompassing diverse applications like Vehicle-to-Grid, Vehicle-to-Building, and more. By delving into the real-life conditions of implementing V2X strategies in parking lots, this report aims to unravel the potential benefits and challenges associated with this innovative approach. Through empirical demonstrations and data-driven analyses, we seek to shed light on the optimal integration of EVs into the broader energy ecosystem, marking a significant stride towards sustainable and efficient transportation and living solutions.

Within this context the UC specifications, development, installation, commissioning, demonstration and evaluation planning for the Danish demo presented in this deliverable represents a stepping stone towards integration of renewable energies, grid and EVs. The main objective achieved so far was the implementation and evaluation plan for employing and evaluating smart charging strategies and V2X solutions in the Danish Demonstrator.

This deliverable delineates comprehensive strategies aimed at the optimal management of parking lots, with a primary emphasis on a semi-public building equipped with a parking facility. The strategies outlined herein go beyond conventional parking management approaches, incorporating innovative solutions tailored to enhance efficiency, sustainability, and integration with renewable energy sources.

The semi-public building serves as a focal point for the implementation of these strategies, emphasizing the intricate balance between effective parking lot utilization and the integration of renewable energies. This document explores a range of considerations, including smart parking solutions, and the integration of EV charging infrastructure. By addressing the unique challenges and opportunities associated with semi-public parking lots, this deliverable aims to provide actionable insights and guidelines for stakeholders involved in the planning, design, and management of such facilities. The strategies outlined herein aspire to go beyond conventional parking management approaches and contribute to the creation of intelligent, functional and environmentally conscious parking solutions, by incorporating innovative solutions tailored to enhance efficiency, sustainability, and integration with renewable energy sources.

In the process of designing a semi-public parking lot in Risø, office areas, the plan involves incorporating six chargers to accommodate twelve EVs. The primary objectives for this configuration, which includes six chargers catering to a maximum of twelve connected cars, includes design considerations, managing power limitation and sharing among various car combinations, synchronizing charging with real or simulated renewable energy generation, maintaining phase balance in the electrical system, implementing energy scheduling with defined priorities, introducing a charging model based on price or Carbon Dioxide (CO_2) emissions, spot-based, ensuring robustness against communication losses through a low-power mode, and incorporating mechanisms for frequency control. Given the available grid capacity of 43 kW, 63 A 3p, the system is designed to achieve a 33% utilization factor, 43 kW compared to 132 kW. This utilization factor signifies an efficient utilization of the grid capacity in the proposed charging system.

A new pilot project at Campus Bornholm involves the deployment of six chargers catering to twelve EVs. The primary goal is to demonstrate the technical feasibility of an autonomous distributed charging process for independently controlled EVs, that fulfils grid services and optimizes the utilization of locally produced renewable energy. Additionally, the project seeks to showcase and compare the benefits of Vehicle to Grid with V2X in both parking lots, UC7, and buildings, UC5. It aims to measure power exchange rates between parking lots and the distribution grid, particularly considering demand response programs, UC3, based on price signals sent by the distribution system operator, UC12. The demonstration will focus on the impact of price signals. The project will also involve phase switching/shuffling to optimize power distribution. With a grid capacity of 43 kW, 63 A 3p, the design aims for a 33% utilization factor, 43 kW compared to 132 kW, emphasizing efficient utilization of the available grid capacity.

1.2 Relationship with Other Deliverables

Deliverable D9.1 presents the detailed description and implementation of the UCs in the Danish Demo. It was prepared in parallel with the rest of the demos taking part in EV4EU. Hence, this deliverable is relevant with D6.1 “Implementation plan for the Azores demo”, D7.1 “Detailed definition and implementation plan of Slovenian Demonstrator” and D8.1 “UC specifications and demonstrator deployment plan”. Each one of the above describes and defines the demonstrations that will be implemented by Portugal, Slovenia, and Greece respectively.

This deliverable follows and is based on the regulation aspects presented in D1.3 “Regulatory opportunities and barriers for V2X deployment in Europe” [1] and the business modelling categories implemented in D1.4 “Business models centred in the V2X value chain” [2]. In addition, it consolidates and finalizes the corresponding UCs described in D1.5 “V2X Use-cases repository” [3].

On the other hand, the control features evidenced within D2.1 “Control strategies for V2X integration in houses” [4], D2.2 “Control strategies for V2X integration in buildings” [5] and D2.3 “Optimal management of V2X in parking lots” [6], serve as a starting point for equipment specification and for the definition of the control, communication, and electrical architectures.

On that last subject, it is important to mention the information exchange needs in D5.1 “Information Exchange needs to enable different UCs” [7] and the interoperability requirements in D5.2 “Standardisation gap analysis for new V2X related Business Models” [8] also contributed to the definition of these architectures.

The present deliverable primarily serves as a basis for the installation, commissioning, operation, maintenance, and monitoring activities to be described in D9.2 “Danish demo commissioning and start-up report for the Danish demo”. Nevertheless, it should also constitute a foundation for the development of the V2X management platform in D5.5 “Open V2X Management Platform”.

1.3 Structure

This document is divided into six sections. Section 1 introduces and describes the D9.1, the Danish demo. Section 2 provides a detailed description of the Risø pilot site, including the roles of actors involved, the installation and deployment processes along with the corresponding demonstration plans and timelines. Section 3 provides a detailed description of the Bornholm pilot site, including the roles of actors involved, the installation and deployment processes along with the corresponding demonstration plans and timelines. Section 4 defines and illustrates the KPIs. Section 5 provides conclusions on this deliverable and Section 6 the references.

2 Risø Pilot Site Description

This section is focused on the first Danish demonstration site, Risø. Firstly, in Subsection 2.1, an overview of the pilot location is given, including a summary of technical specifications of the charging infrastructure deployed as part of the EV4EU project. Subsequently, Subsection 2.2 describes how the charging infrastructure is integrated within SYSLAB, a smart energy lab located in Risø. Subsection 2.3 presents the control architecture for managing the charging cluster, including information on communicating paths and data exchange.

2.1 Overview of the Pilot Location Characteristics

Risø is a research campus of DTU located in Roskilde and showcases the operation of workplace EV charging infrastructure. The charging cluster deployed as part of the EV4EU project comprises six AC chargers, each of which provides a maximum current of 32 A, corresponding to a power of 22 kW when using 3 phases.

The chargers have two outlets (Figure 1), providing the opportunity for twelve EVs to be connected at the same time. The charging infrastructure is integrated via a 63 A grid connection (43 kW using 3 phases), and managed through a load management system enabling the maintenance of aggregated consumption below a specified threshold. This offers various benefits, e.g., preventing component overloading or the provision of both local and external services, such as peak shaving, increasing self-sufficiency, and frequency control [9][10].

Figure 1: Charger at Risø parking lot.

The preparatory work for the infrastructure deployment is well-advanced. A cable tube has been installed at the workplace parking lot, preparing the seamless installation of the six chargers (Figure 2). The chargers are connected to an electrical cabinet at the side of the parking lot, which serves as the Point of Common Coupling (PCC) for the grid integration of the installed Electric Vehicle Supply Equipment (EVSE).

Figure 2: Charging infrastructure in Risø. 1) Chargers; 2) PCC cabinet for all EVSE connections; 3) Cable tube for connecting chargers to PCC cabinet.

2.2 SYSLAB Integration

The charging cluster will be integrated within SYSLAB, a smart energy system lab with distributed units for both production, consumption, and energy storage [11]. This sophisticated system connects twelve substations (Figure 3), bridging six distinct physical sites on campus, through eight kilometres of distribution cables (Figure 4). It offers a diverse array of around 40 different energy resources, including PV, wind turbines, and fossil generation sources. Moreover, SYSLAB features energy storage options like lithium-Ion batteries, vanadium redox-flow technology, and supercapacitors.

Integrating the EV charger cluster into the SYSLAB system provides a unique platform for demonstrating the coordination of smart EV clusters with distributed energy resources [12][13]. The cabinet in Figure 2 includes additional connection options, in particular, another 63 A and four 32 A grid connections, which can be utilized for further extensions of the setup.

Coordinated charging in EV clusters through load management systems provides various benefits [16]. Besides enabling the integration at grid-constrained locations [17], the capability of controlling the aggregated cluster power unleashes the flexibility potential of EVs for services behind and in front of the meter [18]. Specifically, EV clusters can provide peak shaving to increase self-sufficiency and self-consumption [19], and are suitable for ancillary grid services [20][21].

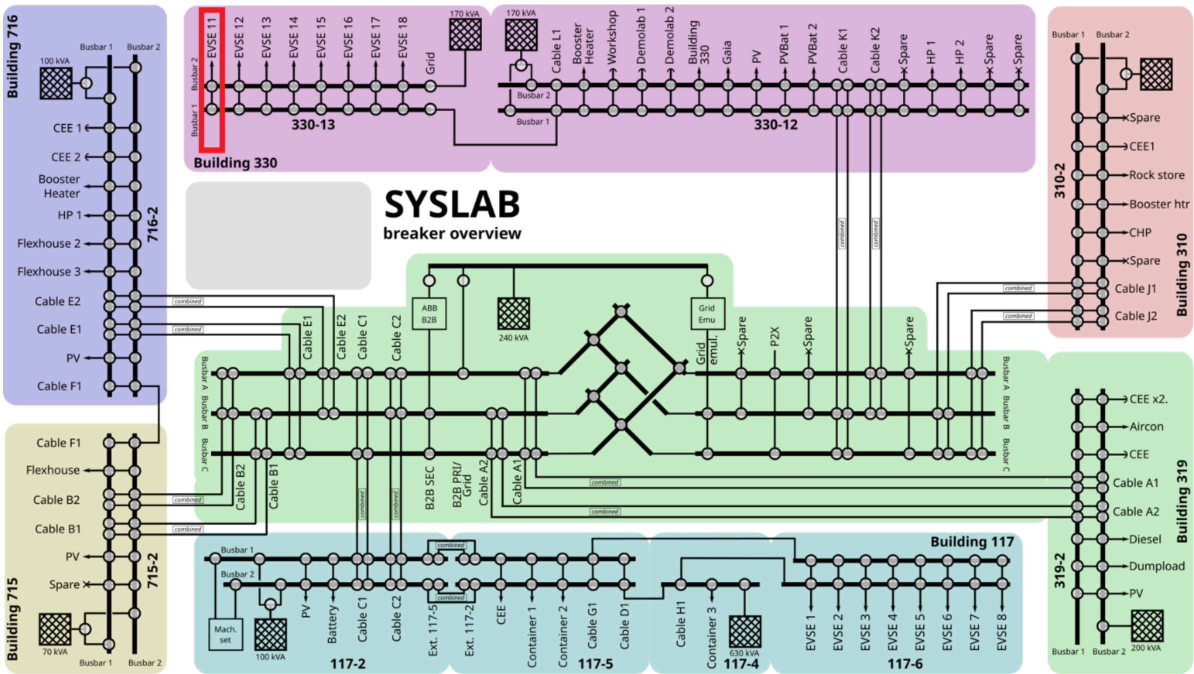

Figure 3: Schematic overview of the electrical SYSLAB nodes. The cluster connection point is highlighted as EVSE 11.

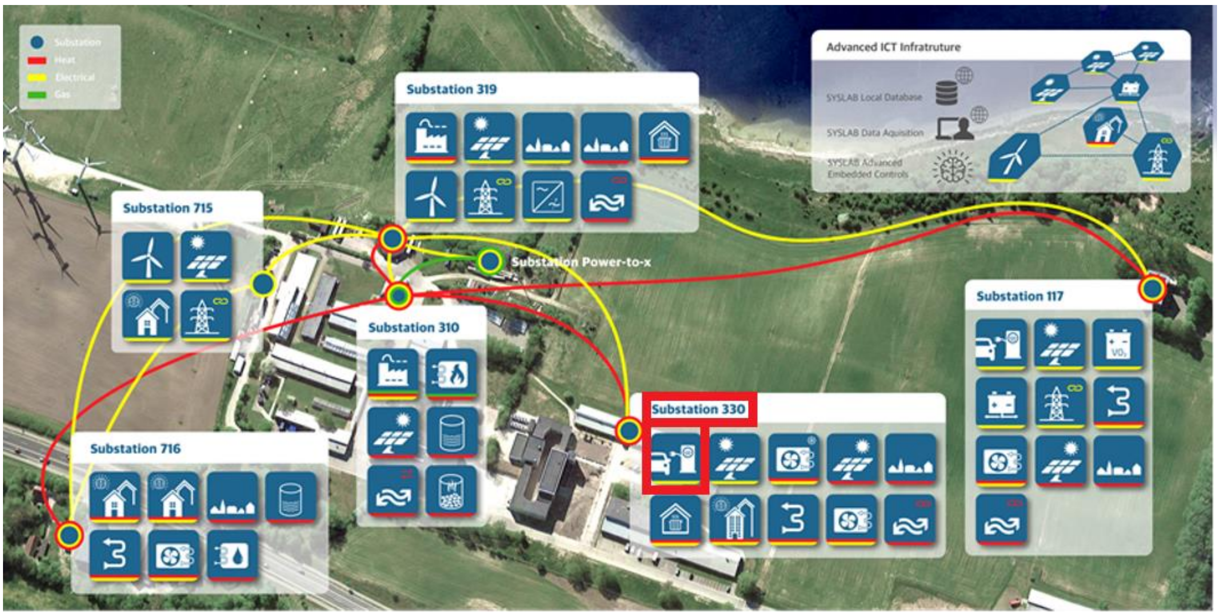

Figure 4: Geographical overview of SYSLAB. The cluster is highlighted in Substation 330.

2.3 Control Architecture

A particular focus of the demonstration activities in Risø is on load management solutions with distributed control architecture, enabled through the implementation of smart chargers with autonomous control functionality [14][15]. Specifically, each charger deployed in this project is equipped with a controller that enables the charger to make autonomous control decisions. This facilitates distributed control schemes where all chargers are provided with global quantities, such as the cluster reference power and the actual cluster consumption, based on which all chargers individually control their respective charging session to collectively meet the cluster requirements.

The distributed architecture includes a global controller, Cloud Aggregator (CA), and local controllers, Virtual Aggregator (VA). The CA receives the inputs from outside the PCC, performs the first layer of control, and communicates the power set point to the VA. The VA is assumed to reside directly inside the chargers, where each of them is controlling the power output for each plug. For the test performed by DTU however, they are located on Beaglebone (BB) microcontrollers outside of the chargers. This provides better adaptability of the setup throughout the development process. The microcontrollers used for DTU's research are shown in Figure 5 and enable a simple interface to the control of the chargers.

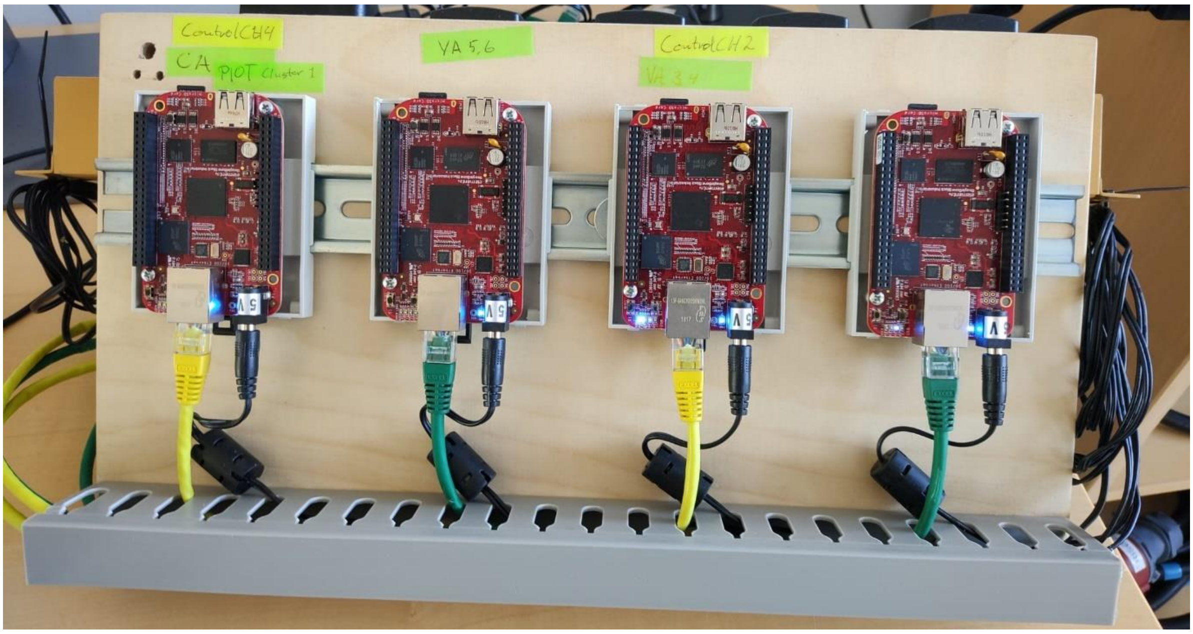

Figure 5: BB microcontrollers for the VAs of three chargers and the CA.

The overall communication structure of the system is described in Figure 6.

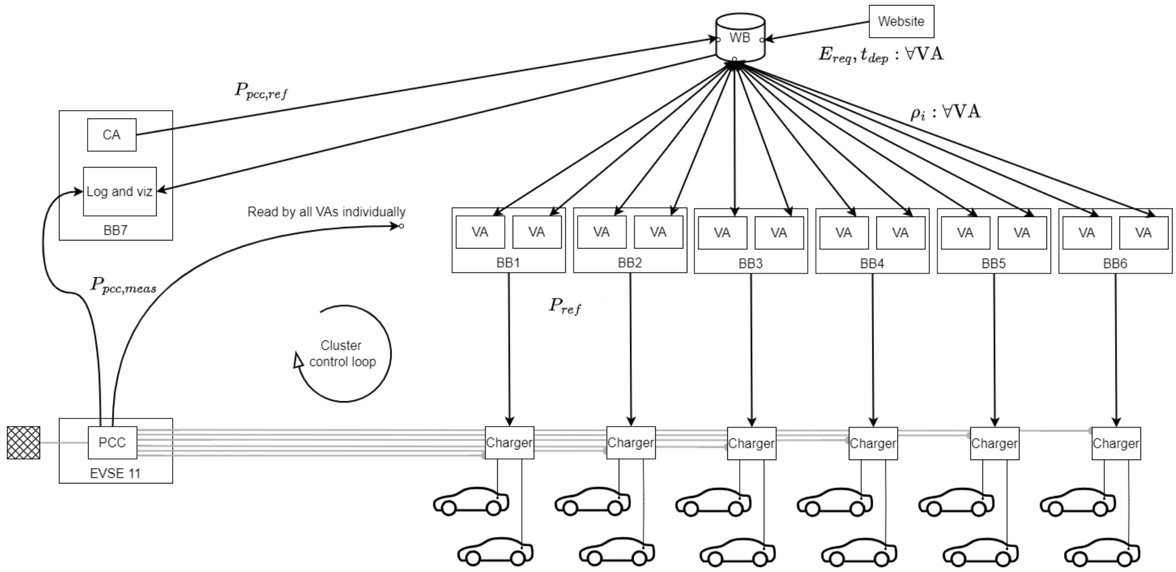

Figure 6: Communication architecture of the system.

The CA runs in defined modes that decide which input signals to react to, respectively. According to the different modes, the CA will continuously communicate a power set point. The VAs use a local shared database and operate in the following manner:

- From the CA they receive the power set point to follow.
- From the website they receive the users' inputs (time of arrival, time of departure and energy requested) to calculate the priority (depicted as ρ in Figure 6) to give to each EV.
- They will then distribute their current priority to the other VAs.
- Lastly, all the VAs receive the power measured at the PCC from measuring unit EVSE 11.

Having the above-mentioned inputs, each VA will compile the error between the power set point given by the CA and the power consumed by the parking lot. They will then adjust the power given to the controlled plug according to the priority given to the cars. A stronger priority results in a more aggressive VA. If a VA has a low priority, the charging session of the corresponding user will be scheduled for later. The VAs must also react to real-time changes in the power consumption occurring during new arrivals or departures, or when EVs change their charging power. This is particularly important since EVs have specific battery and charging characteristics that can vary from model to model [22][23].

The two channels of communication are the custom-made Whiteboard (WB) and the Amazon Web Services (AWS). These solutions are used to store and retrieve the last communication set points. AWS is responsible for the communication between the VAs and the charger actuators, while WB is the local shared data storage responsible for the communication between all the control components.

The CA is the central unit of the cluster which enables active responses to signals from other entities. The power reference of the cluster is broadcasted from the CA to all VAs that act in collaboration to ensure the cluster's power consumption matches. The CA has multiple modes that enable the cluster to respond to the most suitable signals. In the lab in Risø, tests have been performed with the following modes:

- **Transformer protection**: The consumption of the cluster stops immediately if the CA receives a signal that the transformer connecting the cluster to the main grid is overloaded.
- **Renewable following**: A signal of power produced by a nearby PV, or wind turbine can be used as input and the cluster will level out the production with its consumption. It will thereby improve self-consumption of locally produced power.
- **Frequency regulation**: The CA takes the frequency as real time input and via droop control converts it to the cluster power reference. It enables the CA to provide frequency regulation.

To enable data handling and continuous monitoring of the system the BB microcontroller hosting the CA further contains a file that captures events (Log) and a Python Viz script for visualization. This is not participating in any control algorithm but ensures that all the necessary data from the WB and PCC is visualized and collected for logging.

3 Bornholm Pilot Site Description

This section is focused on the second Danish demonstration site, Campus Bornholm. Firstly, an overview of the pilot location is given, including documentation of the deployment status of the charging infrastructure. Subsequently, the second subsection describes the user profile for Campus Bornholm. The third subsection presents the control architecture, followed by a description of the app used for initiating charging sessions in the fourth subsection.

3.1 Overview of the Pilot Location Characteristics

The pilot site on the island of Bornholm is located at the local educational institution Campus Bornholm, where the high school, vocational training and health care educational institutions are based. More than 1,500 students under the age of 18 and 4,000 adults attend Campus Bornholm each year. As a result, the institution is mostly used from 07:00 to 16:00 every day.

There is a 180 kW PV system and a sizable parking lot on Campus Bornholm. During the day, the parking lot is reserved for employees and students, however, after 16:00, the parking lot is open to all free of charge. It has been identified as a suitable charging location in previous research projects, where it provided valuable insights in public charging patterns [24][25]. This parking lot will have six chargers, with each one comprising two outlets. This implies that twelve EVs can be charged at once.

The process of preparing the parking lot with electrical installations for the six chargers was initiated during August 2023 and construction was carried out from September to November 2023. Figure 7, Figure 8, and Figure 9 show different phases of the construction. At the moment of writing this deliverable, the parking lot is ready for installation of the chargers. Thus, the installation of the chargers, which is planned for January 2024, is likely to be completed and the demonstration can be initiated.

Figure 7: Preparing the parking lot for installation of cables.

Figure 8: Cables are in the ground and poles are ready to be fixed in the ground.

Figure 9: Poles are ready for installation of chargers.

Figure 10 depicts an overview of the parking lot which, besides the parking spaces, includes the transformer station from where power is available. The transformer is identified as ST596, 10 kV to 0.4 kV on the charger side. At the transformer station the main meter for measuring power use for billing purposes will be installed. Adjacent to the transformer station, a cable cabinet is installed for safety.

Figure 10: Overview of the parking lot. 1) Location of chargers. Each location marked with "1" will host two chargers, on opposite sites; 2) Cable cabinet; 3) Meter cabinet; 4) Transformer.

Inside the cable cabinet, shown in Figure 11, the six relays for the chargers are installed alongside the equipment for measuring power and usage of the chargers.

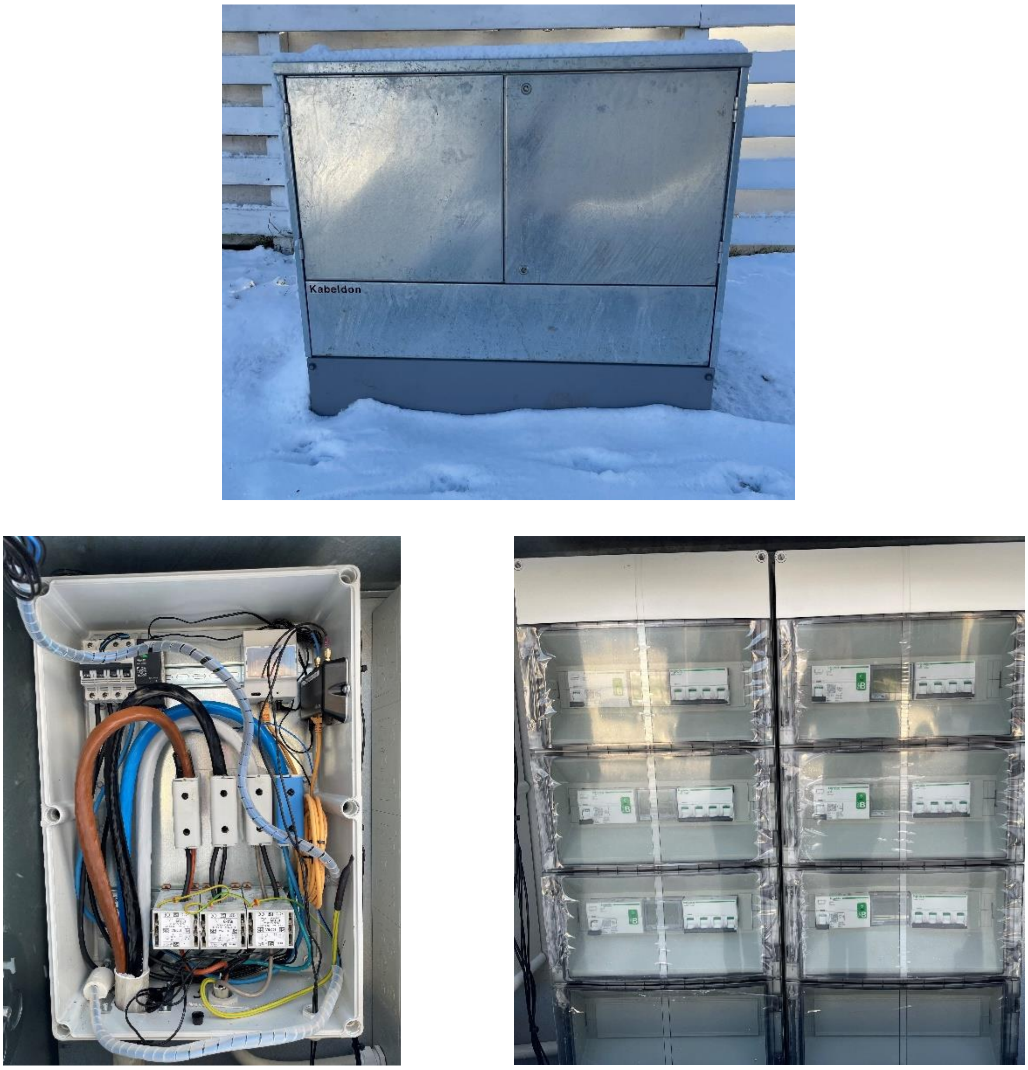

Figure 11: Cable cabinet installed at Campus Bornholm (top), and equipment inside the cabinet (bottom).

The 43 kW feed, which is insufficient for the six chargers (6x22 kW = 132 kW), will supply power to the charging stations. The demonstration further demonstrates the operation of the autonomous VAs with distributed control architecture to provide grid services while operating with constrained network capacity. The system will respond to requests for priority made by a small number of users. DTU and BEOF oversee the 180 kW PV plant on Campus Bornholm, and the latter has access to a control room where it can adjust power output. DTU has set up a weather station and stores PV inverter data at a granularity of 1 second.

3.2 Bornholm Site Users

In Campus Bornholm, it will be possible to perform destination charging, meaning that visitors and users may charge their EVs even if they are not there for charging purposes. The majority of EV owners will park and charge for a long period of time, varying from a couple of hours to 8 hours (a workday with half-hour break), directly correlated with their purpose on site. The end users will most likely be employees and students of Campus Bornholm. However, when the campus is closed in the evening and during the summer period, mainly July, the parking lot will be used by end users from nearby residential areas, or tourists [26].

Campus Bornholm is located in Rønne, a short 10-minute walk from city centre where museums, restaurants, etc., are available. Therefore, it is possible for everyone to access the chargers during summertime, and for tourists to charge at Campus Bornholm while they enjoy the city. Thus, the chargers will be a combined destination and an opportunity to park the car while visiting the town. In addition, the chargers are also available for locals living close to the campus for charging during the evening and night when the school is closed. Since Bornholm is an island with approximately 100 km of road in circumference, the need for daily charging of EVs is highly decreased, and locals have the opportunity to charge only when needed and use the chargers available.

The users can be split into the following three categories:

- Daily users of the campus parking lot (e.g., students, employees, visitors).
- Locals using the chargers instead of home charging.
- Tourists.

This means the chargers may need different settings and options depending on time of year to better accommodate the user needs. In this context, the demonstration activities will provide valuable insights into charging patterns of different user groups.

3.3 Control Architecture

The control architecture will be the same as the one described in Subsection 2.3, hence, a global CA communicating a power set point to local VAs. The VAs will reside directly inside the chargers. They will communicate with a cloud database that is shared between the VAs. The only data that will be shared between the VAs will be the priority value of each outlet, i.e., the priority value of each connected EV. The outlet power will then be calculated based on the outlet priority value, summation of all priorities, and the power set point. The outlet priority is calculated with the app user input values (time of arrival, time of departure, and energy requested). The app user input will be sent directly to the corresponding VA, namely, the VA which is controlling the outlet that the user plugged into, and no other VA will receive these values.

The initial configuration with app will use the maximum limit for the parking lot, 43kW. This will be the power set point to share between the outlets. This will be shared in accordance with the outlet priority values [15].

The VAs use a cloud shared database and operate in the following manner:

- From the database they receive the parking lot power set point.
- From the database they receive the user input (time of arrival, time of departure, and energy request).
- They send charging session information to the database (measured power and delivered energy).
- They send the calculated priority values to the database.
- They received all priorities from the station group.

The app uses a cloud shared database and has the following communication paths:

- It sends start and stop signals for charging sessions to the database.
- It sends the user inputs (arrival time, departure time, and energy request) to the database.
- It receives the available charging points from the database.
- It receives the energy delivered and the current power consumption for active charging sessions from the database.

AWS is the channel for communication between the chargers and user apps. This solution is used to store the charger configuration, charger state, and charging session information.

3.4 User App

The app gives the EV user an overview of the charging session information. From the app, the user can start a charging session by linking with a charging station. The user can link to a charging station by scanning a Quick Response (QR) code or typing the charger Identification (ID), as shown in Figure 12, where the QR code and charger ID will be located on the charger above its respective outlet.

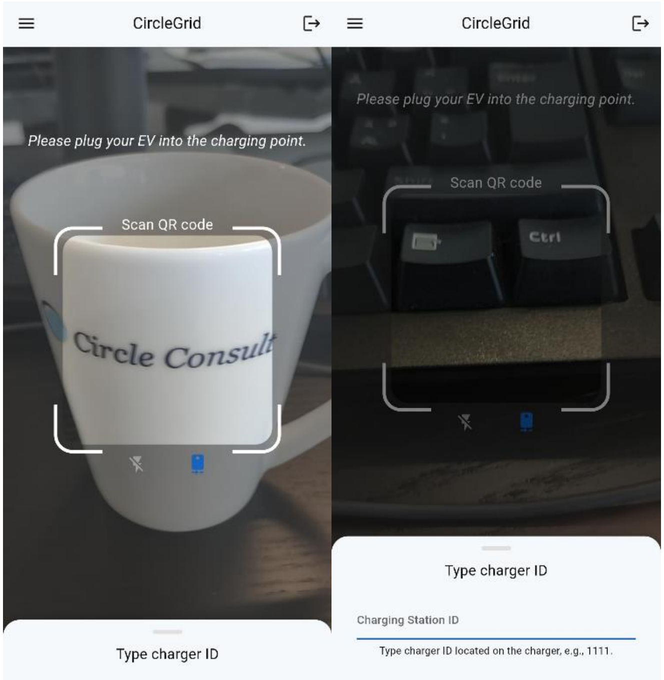

Figure 12: The app user interface for either scanning a QR code (left), or type in the charger ID by dragging the panel up (right).

To start a charging session, the user must input the desired session parameters, i.e., the energy request (in kWh) and their estimated time of departure, as shown in Figure 13. Before the user can start the charging session, they will need to accept the approximate price for the charging session, derived from the energy request input and the current price per kWh (DKK/kWh). This will be handled with MobilePay, ensuring secure payment. Then the user can start the charging session by sliding the blue button to the right (see Figure 13).

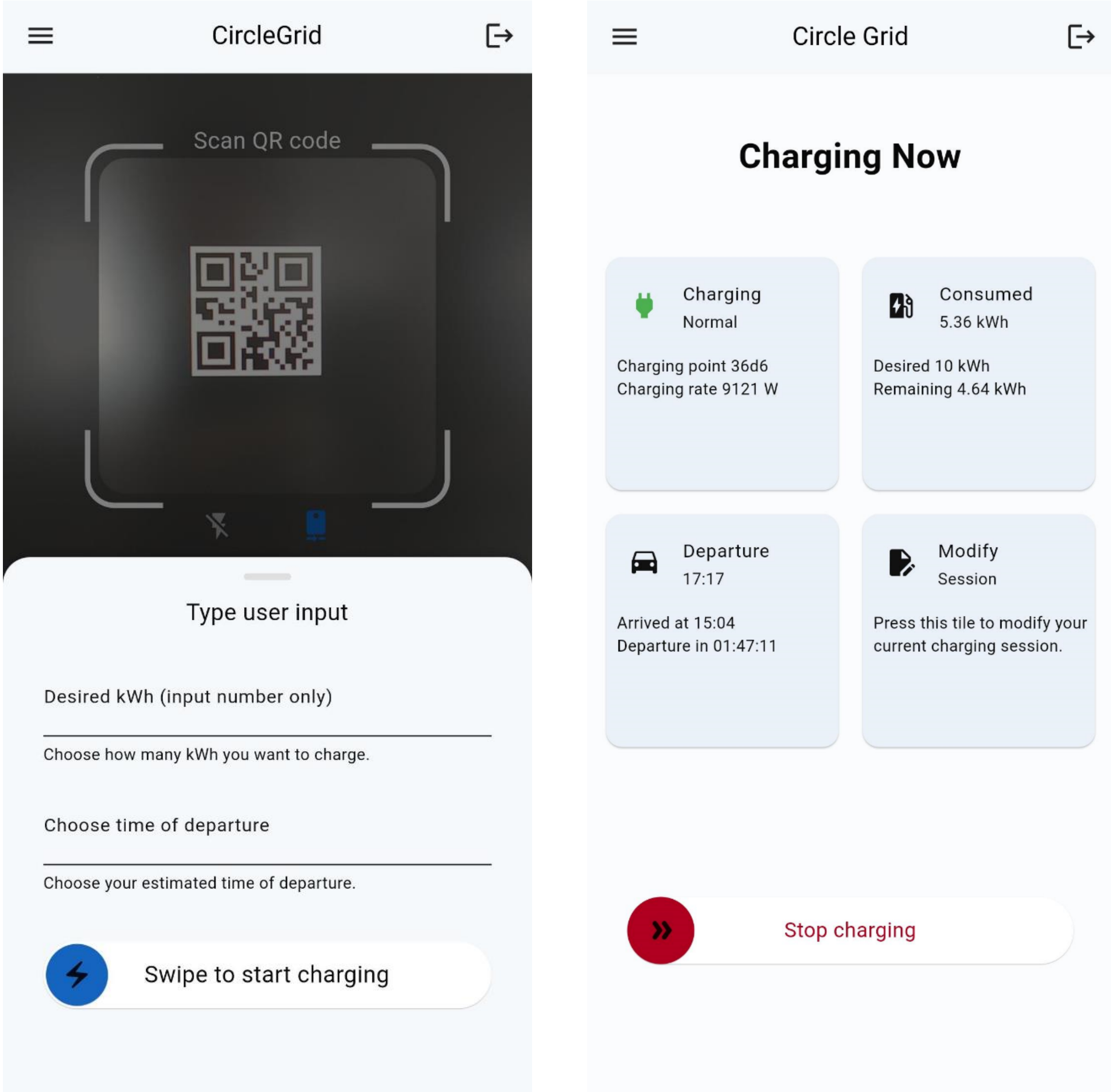

Figure 13: The app user interface. Left: Input of charging session parameters; Right: Charging session information displayed for the user.

The charging session input parameters can be modified at all times during the charging session, e.g., if the user has a change of plans, then they can configure the energy request and/or the time of departure. The user can also stop the charging session at any point in time, either with the app or at the EV. The status screen will be displayed during an active charging session. On the status screen the user will be able to see the current power consumption on all phases, the current input parameters, the energy delivered, the remaining energy until energy request has been fulfilled, and the time until the departure time, as seen in Figure 13.

From the app the user can browse its charging history. If the user is assigned as a parking lot owner, then they will have the option of configuring the price per kWh for the corresponding parking lot. The parking lot owner role can only be assigned with admin privileges during the setup of the parking lot and can be at a later point in time reassigned to another user account if desired.

4 Key Performance Indicators

The following definition of KPIs is integral to the evaluation plan, with a majority of the KPIs linked to the Business Use Cases (BUCs) associated with the demonstration in Work Package (WP) number nine. The KPI analysis encompasses not only the description of each KPI but also sets indicative targets to gauge the project's success when the KPIs are calculated.

The assessment criteria are structured into distinct dimensions, recognizing the multifaceted nature of the project's impact. This includes technical considerations, such as the reduction in operational constraints and demand fluctuations, alongside environmental assessments like the impact on emissions. Additionally, the plan addresses social aspects, demonstrated through the evaluation of user participation and satisfaction, offering a comprehensive understanding of the project's societal implications.

Furthermore, the plan incorporates service-related indicators, examining the utilization of flexibility and the requested flexibility by relevant entities. These indicators are crucial in evaluating the effectiveness of operational tools. The evaluation plan also encompasses economic and market-related considerations, evaluating information and communication technology costs and the economic impact on involved stakeholders. This provides insights into the project's financial viability and its implications for the market.

By considering a diverse array of factors and KPIs, the evaluation plan aims to provide a comprehensive assessment of the project's performance, ensuring that all significant aspects are considered.

The list of KPIs may potentially be revisited as the demo deployment and demonstration progress, to encompass all addressed objectives and issues of the Danish demo.

Table 1: KPIs colour legend.

KPI type color
Economic
Technical
Users
Environmental

Table 2: Key Performance Indicators.

KPI ID	KPI Name	KPI Type	Description	Measurement/Calculation	[EV4EU] WP9, BUC
KPI_DK_1	Cost of availability	Economic	Cost of reserved flexibility.	Calculation (euros)	BUC 3, 7
KPI_DK_2	Cost of provided energy	Economic	Cost of the used flexibility.	Calculation (euros)	BUC 3, 7
KPI_DK_3	Cost of Charging	Economic	Cost of charging for EV users and charge point operators.	Calculation (euros)	BUC 3, UC 5
KPI_DK_4	Self-consumption	Economic	Share of locally produced energy consumed locally.	Calculation (%)	UC 5
KPI_DK_5	Self-sufficiency	Economic	Share of local consumption provided by local production.	Calculation (%)	UC5
KPI_DK_6	Requested flexibility	Technical	The amount of flexibility requested by the system operators.	Measurement (kW)	BUC 3, 7
KPI_DK_7	Charger efficiency	Technical	Charger efficiency in terms of active power and power factor.	Measurement (%)	BUC 3, 7, UC 5
KPI_DK_8	Up-time of chargers (Resilience)	Technical	Ratio of up-time and total operational time.	Measurement (%)	All
KPI_DK_9	Scalability	Technical	Software and hardware complexity as a function of the number of chargers.	Calculation (#)	All
KPI_DK_10	Setpoint compliance	Technical	Difference between setpoint and actual power: accuracy and delay.	Measurement (kW, s)	All

KPI_DK_11	Charging success ratio	Technical	Requested kWh needed versus actual kWh gained per charging session.	Measurement (KWh)	All
KPI_DK_12	Peak power reduction	Technical	Peak power in a defined time period. Can focus on a cluster level (peak shaving), or on a distribution grid level.	Measurement (kW)	BUC 3
KPI_DK_13	Total capacity of charging stations	Technical	The total installed capacity of charging stations.	Calculation (kW)	All
KPI_DK_14	Potential flexibility from EVs	Technical	Potential flexibility in terms of time, power, and energy. Can also measure the amount of activated flexibility.	Calculation (kW, kWh, s)	All
KPI_DK_15	Charging behavior	Users	Duration (parking, charging), maximum power, and energy of charging sessions, with and without provision of flexibility service.	Measurement	All
KPI_DK_16	User inputs	Users	Anticipated charging time and required energy.	Measurement	All
KPI_DK_17	User satisfaction	Users	Satisfaction of users with the service, with and without service provision, e.g., surveys, complains, feedback etc.	Measurement	All
KPI_DK_18	Number of EVs	Users	Number of EVs charged & number of individual users.	Measurement (#)	All
KPI_DK_19	Impact on CO2 emissions	Environmental	How much the offered services increase/decrease the CO2 emissions in the system.	Calculation (g/kWh)	All

5 Conclusions

The present document summarizes the main specifications for the UCs to be demonstrated in Denmark. The Danish demonstration takes place at two locations: Risø and Campus Bornholm. At each location, the deployment plan includes the installation of six AC chargers (22 kW) with two outlets each, providing the opportunity for twelve EVs to be connected at the same time. The charging infrastructure is integrated via a 43 kW grid connection, and operated through a load management system.

Risø is a research campus of DTU located in Roskilde and showcases the operation of workplace charging infrastructure accessible for employees and visitors. The charging cluster will be integrated within SYSLAB, a smart energy system lab with distributed units for production (e.g., PV, wind), consumption (e.g., smart home, heat pumps), and energy storage (e.g., batteries). This provides the unique opportunity to demonstrate the coordination of smart EV clusters with distributed energy resources. A particular focus of the demonstration activities in Risø is on load management solutions with distributed control architecture, enabled through the implementation of smart chargers with autonomous control functionality. The chargers were recently installed on the campus and are currently being integrated in SYSLAB and the existing software architecture.

The parking lot of Campus Bornholm in the main town Rønne is publicly accessible and will eventually be used by students, employees, residents, and tourists. Users of the charging infrastructure will start their charging sessions through an app, which was developed as part of the EV4EU project. The app allows the user to provide key inputs, such as the anticipated parking time and the required energy, which enable the load management system to consider user preferences while controlling the overall cluster consumption. The construction work at this location has been recently completed, including the installation of underground cables, charger poles, and electric meters. In the upcoming weeks, the six chargers will be prepared, shipped, and installed on-site.

The deliverable presented a detailed overview of the technical installations at both locations and further described the data acquired throughout the demonstration activities. Besides general charging session parameters (charged energy, charging time, connection time), the high-resolution power measurements on both charger and cluster level allow a thorough analysis of test cases. Finally, the deliverable proposes 19 KPIs for quantifying the performance and impact of the demonstration activities. The KPIs are organized in four main categories, addressing economic, technical, user-related, and environmental impacts. As a next step, Task 9.2 will finalize the already well-advanced deployment and commissioning of the charging infrastructure at both locations, followed by the start-up of operation.

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