



AI-informed Holistic Electric Vehicles Integration Approaches for Distribution Grids

D7.2

Construction, Nordic

May 2026 (M24)



**Co-funded by
the European Union**

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101160665.

DELIVERABLE DETAILS					
Project	AHEAD	Grant Agreement	101160665		
Deliverable Type (R, DEM, DEC)	DEM	Deliverable Title	Construction, Nordic		
Status	Final	Month due	May	Date	31/05/2026
Lead author	Mattia Marinelli (DTU)				
Co-author(s)	Igli Bisha (DTU), Tommaso Reschiglian (DTU), Leoni Winschermann (DTU), Lisa Calearo (Spirii), KNUDSEN Jesper(Spirii), Atle Brendryen (Kempower), Frank Judell (AMINA), Esko Heino (Kempower), Amir Safdarian (Kempower)				
Peer reviewer	Lucas Pereira (IST-ID)				
Dissemination level	PU - Public				
HISTORY OF CHANGES					
Document history	Date	Version	Submitted by	Comments	
	31/05/2026	V0.1	DTU	Table of content ready	
	16/06/2026	V0.2	DTU	Deliverable finalized. Missing final installation of the fast charging demo	
	29/09/2026	V0.3	DTU	Feedback after internal review included	

	30/09/2026 (delay)	V1.0	POLIMI	Uploaded document
--	-----------------------	------	--------	-------------------

LEGAL DISCLAIMER:

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101160665.

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

ACKNOWLEDGEMENTS

We refer to people who contribute to the project without being the part of Task 7.2

EXECUTIVE SUMMARY

This deliverable presents the commissioning and start-up activities carried out in Task 7.2 of the AHEAD project EU Horizon Europe, focusing on the preparation of the Nordic demonstration sites at the DTU Risø Campus for operational deployment.

Building upon the specifications, test cases, and system design defined in Task 7.1, Task 7.2 addresses the practical realization of the demonstration environments. This includes the installation, integration, and validation of both slow AC charging infrastructure and fast DC charging systems, together with supporting assets such as battery energy storage systems (BESS), renewable generation, and communication platforms.

The objective of Task 7.2 is to ensure that all components of the demonstration sites are fully operational, interoperable, and ready for the execution of the defined use cases in subsequent tasks (T7.3 and T7.4). Particular emphasis is placed on enabling coordinated operation of heterogeneous charging technologies under constrained grid conditions, while ensuring reliable communication, controllability, and data acquisition.

The demonstration sites are integrated within the DTU Risø SYSLAB infrastructure, allowing high-resolution monitoring and control across all system components. The slow-charging demonstration focuses on multi-brand AC charger aggregation and smart load management, while the fast-charging demonstration explores high-power DC charging combined with energy storage and renewable integration.

A central role in the system architecture is played by the Spirii platform, which provides the communication and control interface between the charging infrastructure and the control framework. Through this integration, both demonstrations enable real-time control, data collection, and system-level coordination.

The deliverable documents the implemented system architecture, commissioning procedures, start-up process, and operational readiness of both demonstration sites. It further describes the data acquisition setup, visualization framework, and user accessibility, ensuring that all prerequisites for executing the defined test cases are fulfilled.

Overall, Task 7.2 marks the transition from system design to real-world operation, establishing a fully functional experimental platform for evaluating advanced EV charging control strategies, interoperability, and flexibility services under realistic conditions.

Table of Contents

INTRODUCTION.....	7
1.1. Background and Objectives	7
1.2. Demonstration Overview - DTU Risø Campus	7
1.3. Structure.....	8
2. Test Case Definition and System Architecture	9
2.1. Overview of Test Cases	9
2.2. Overall System Architecture.....	10
3. Slow Charging Demonstration	12
3.1. Implemented System Overview.....	12
3.2. Physical Layout and Deployment	12
3.3. System Architecture.....	13
4. FAST Charging Demonstration.....	16
4.1. Implemented System Overview.....	16
4.2. System Architecture.....	17
5. User Interface and Accessibility.....	20
6. Data Acquisition and Storage.....	22
7. Visualization of EV Charging and Energy System Signals	24
8. Conclusion	26
Bibliography	27
9. ANNEX	31
9.1. Supporting Technical Documentation	31

List of Figures

Figure 1 Schematic of the Nordic demo sites.	10
Figure 2. testing framework overview.....	11
Figure 3. Cluster layout slow charging demonstration.	13
Figure 4. System architecture. Layer 2 and 3 have been specifically developed as part of the AHEAD project.....	14
Figure 5. SPIRii-Specific Message-Driven Control Execution.	15
Figure 6. Cluster layout fast charging demonstration.....	16
Figure 6. Fast charging demo site with the installation completed.	17
Figure 7. EMS first phase architecture.	18
Figure 8. EMS second phase architecture.....	19
Figure 9. EMS third phase architecture.	19
Figure 10. Spirii Go app AHEAD DTU chargers.	20
Figure 11. Spirii Connect	21
Figure 12. Overview of the EV charging system architecture. Data flows (green), control signals (orange), and visualization paths (blue) are shown, with key variables indicated along each connection.....	22
Figure 13. EV charger power dashboard interface showing real-time charger power, charger status indicators, aggregated phase power at the EVSE cluster level, and short-term forecasts of electricity price and CO2 emissions.	24

List of Tables

Table 1. Overview of test cases for the Nordic slow charging demonstration.	9
Table 2. Overview of test cases for the Nordic fast charging demonstration.....	10

INTRODUCTION

In this section, we outline the objectives, methodology, and structure of this deliverable.

1.1. Background and Objectives

The objective of Task 7.2 is to operationalize the demonstration environments defined in Task 7.1 by carrying out the commissioning and start-up of both slow and fast charging infrastructures at the DTU Risø Campus.

While Task 7.1 focused on defining use cases, test cases, system specifications, and key performance indicators, Task 7.2 is concerned with the physical and digital realization of these elements. This includes the installation and integration of EV charging infrastructure, energy storage systems, renewable generation assets, and communication platforms, as well as the validation of their coordinated operation.

A key objective is to ensure interoperability across multi-brand charging equipment and seamless integration with the backend platform Spirii, enabling unified monitoring and control of heterogeneous assets. In addition, the task establishes the data acquisition and processing framework required for evaluating system performance and executing the defined test cases.

The outcome of Task 7.2 is a fully commissioned and operational demonstration platform, capable of supporting advanced control strategies, flexibility provision, and experimental validation under real-world constraints, thereby enabling the execution of Tasks 7.3 and 7.4.

1.2. Demonstration Overview - DTU Risø Campus

The DTU Risø Campus serves as the main Nordic demonstration site of the AHEAD project EU Horizon Europe, where the infrastructure defined in Task 7.1 has been implemented, integrated, and commissioned to support real-world experimental operation.

The demonstration environment consists of two complementary setups: a slow-charging AC system focused on multi-brand aggregation and flexibility provision, and a fast-charging DC system integrated with battery energy storage and renewable generation. Both systems are deployed under constrained grid conditions and interconnected within the SYSLAB (<https://wind.dtu.dk/facilities/powerlabdk-facilities/syslab>) multi-energy platform, enabling coordinated monitoring and control.

During Task 7.2, all hardware components—including AC chargers, DC fast chargers and BESS, were installed and integrated into a unified system architecture. Communication between devices and control framework is established through the Spirii platform, ensuring

reliable data exchange and remote controllability of the chargers while the battery is controlled through the Kempower system.

The commissioning process included validation of electrical installation, verification of communication interfaces, and testing of control capabilities across all assets. Following commissioning, the start-up phase activated the system under operational conditions, enabling user interaction, real-time control, and continuous data acquisition.

The resulting platform provides a fully operational testbed for evaluating advanced EV charging strategies, including smart load management, renewable-priority charging, and coordinated operation of heterogeneous resources.

1.3. Structure

The remainder of this deliverable is organized as follows:

Section 2 provides an overview of the test cases defined in Task 7.1 and introduces the overall system architecture that enables their implementation within the demonstration environment.

Section 3 presents the slow-charging (AC) demonstration, focusing on the implemented system, physical deployment, and realized system architecture.

Section 4 describes the fast-charging (DC) demonstration, including the deployed infrastructure, physical layout, and integrated system architecture.

Section 5 outlines the user interface and accessibility, including user interaction via the Spirii platform, authentication mechanisms, and session management functionalities.

Section 6 describes the data acquisition and storage framework, detailing the sources, structure, and handling of operational data collected from the charging infrastructure.

Section 7 presents the visualization of EV charging and energy system signals, integrating charging data with external inputs such as electricity price, CO₂ intensity, and grid-related information for system-level analysis.

Section 8 concludes the deliverable and summarizes the readiness of the demonstration sites for the execution of subsequent tasks.

Annexes provide supporting technical material, including system diagrams, detailed specifications, and supplementary data.

2. TEST CASE DEFINITION AND SYSTEM ARCHITECTURE

2.1. Overview of Test Cases

The Test Cases developed in T7.1 are summarized in Table 1 and 2 below. Each test case directly translates the conceptual and technological objectives of the AHEAD use cases, such as demand response, cybersecurity, flexibility activation, renewable integration, and AI-based grid support-into measurable experiments carried out at the demonstration sites.

Table 1 provides an overview of the test cases considered at the slow charging demonstration at DTU Risø Campus. Additional details about use cases and objectives can be found in Deliverable 7.1.

Table 1. Overview of test cases for the Nordic slow charging demonstration.

TC1	Dynamic Enforcement of Site-Level Power Limits
TC2	Responsiveness & Reliability
TC3	User Acceptance During DR
TC4	DR Strategy Impact
TC5	Optimized Load Utilization
TC6	Optimal vs Heuristic Energy management
TC7	Cybersecurity Assessment
TC8	Distributed vs Centralized
TC9	PV/WIND Priority Charging
TC10	Dynamic Pricing Impact
TC11	AI-Informed Coordinated Charging
TC12	Coordinated Flexibility Activation in VPP
TC13	Grid/Environmental Benefits
TC14	Real-Time Flexibility Provision via CPO-Controlled EV Charging
TC15	AI Grid Impact Prediction

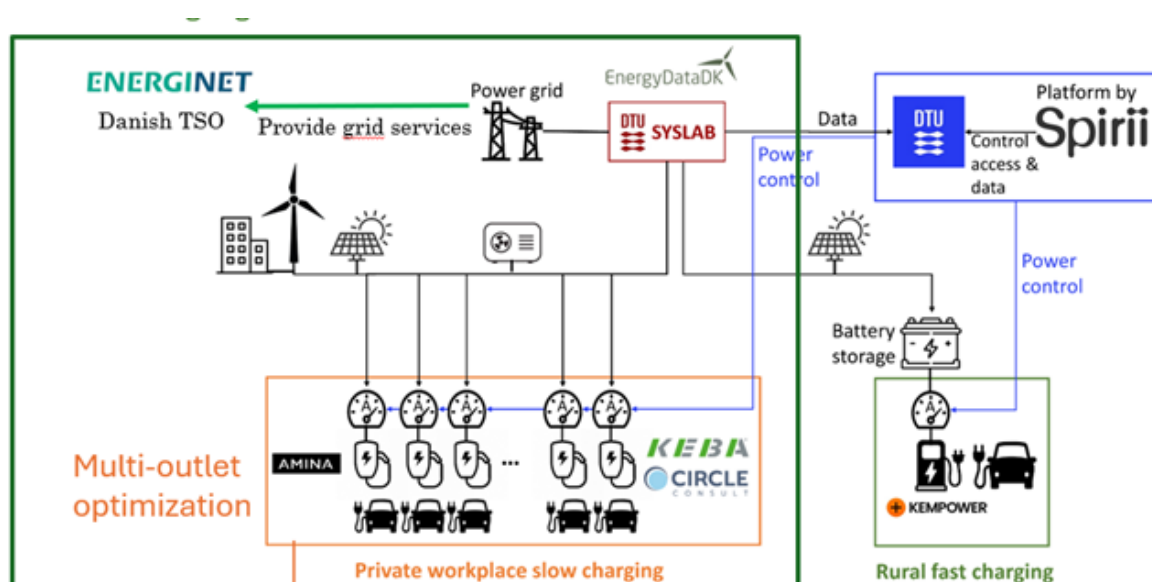
Table 2 provides an overview of the test cases considered at the fast charging demonstration at DTU Risø Campus. Additional details about use cases and objectives can be found in Deliverable 7.1.

Table 2. Overview of test cases for the Nordic fast charging demonstration.

TC1	Flexibility Activation During Grid Peak Load
TC2	Frequency Regulation with BESS
TC3	Coordination Between DSO and TSO
TC4	Cybersecurity assesment
TC5	Smart Power Allocation Under Peak Load
TC6	RES Curtailment Avoidance at High Production
TC7	Dynamic Pricing Impact
TC8	Real-time flexibility provision via CPO
TC9	Emergency Grid Outage Management
TC10	Optimal vs. Heuristic Energy Management
TC11	Coordinated Flexibility Activation in VPP
TC12	Grid/enviromental benefits
TC13	AI grid impact predictions

2.2. Overall System Architecture

A multi-brand cluster of slow AC chargers communicates via OCPP 1.6J with the Spirii backend for centralized control, as shown in Figure 1.

**Figure 1 Schematic of the Nordic demo sites.**

The charging infrastructure is integrated with DTU's SYSLAB, where local RES (PV & wind) signals and measurements are available so that charging can prioritize renewables and respect a site power cap. In parallel, a fast-charging site integrates a KEMPOWER DC charging system with a Pixii battery energy storage system (BESS) and local PV generation to deliver up to 150 kW of charging under a limited 22 kW grid connection, demonstrating hybrid operation, flexibility activation, and grid-supportive control.

Slow and fast chargers are connected to the Spirii backend. Additionally, the Kempower fast chargers also have the Charge eye system control that can include some additional control features as described in the following sessions.

To provide charger and circuit controls to external partners, Spirii has developed the "Test Framework"¹, which provides access to the DTU for controlling the chargers and circuits, as well as for continuously collecting data. An overview of the system is displayed in Figure 2. External partners can at the moment:

- Receive state information, including connector status and power reading
- Set power limit
- Set circuit (cluster) limits

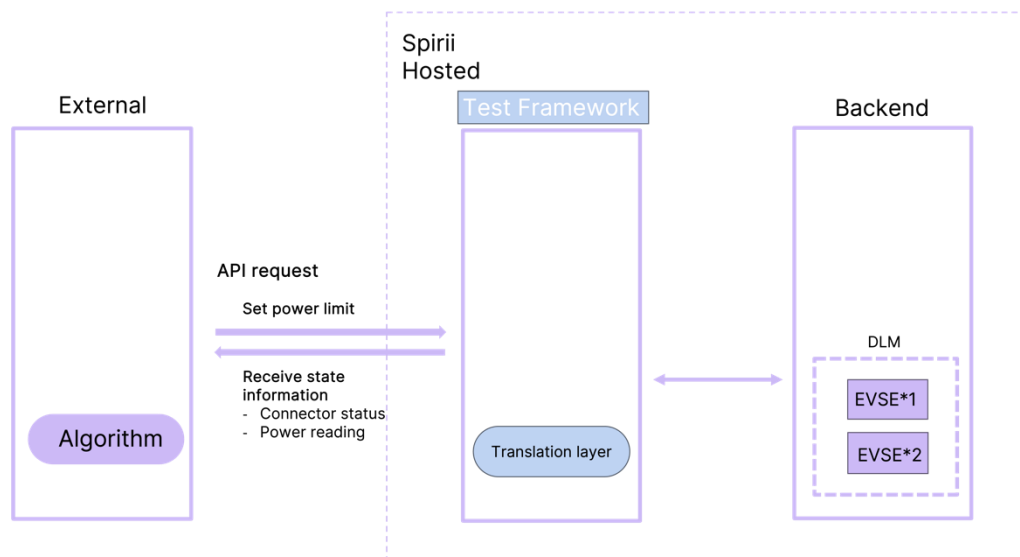


Figure 2. testing framework overview

¹ In collaboration with FLOW and e2flex R&D projects.

3. SLOW CHARGING DEMONSTRATION

3.1. Implemented System Overview

The slow-charging installation has been implemented to evaluate coordinated charging control, multi-brand charger interoperability, and the use of aggregated AC charging loads for grid-flexibility applications. The setup is integrated into the DTU SYSLAB environment and connected to the Spirii platform for control access and data acquisition.

The configuration includes:

- AC chargers distributed across three controllable clusters.
- 7 Amina chargers, 1 NexBlue charger, and 1 Zaptec Pro charger.
- Three 32A AC charging clusters for testing shared-capacity operation.
- Integration with the SYSLAB electrical environment, including local renewable-energy resources and site loads.

The clusters are configured as follows:

- Cluster EVSE 13 - Mixed-brand cluster: 1 Amina charger, 1 Zaptec Pro charger and 1 NextBlue charger.
- Cluster EVSE 15 - Amina cluster: 3 Amina chargers.
- Cluster EVSE 16 - Amina cluster: 3 Amina chargers.

Through the Spirii backend, the chargers can be monitored and controlled under the available cluster capacity. The implemented system enables the evaluation of current allocation, charger responsiveness, communication latency, and coordinated charging performance across homogeneous and mixed-brand charger configurations. Integration with SYSLAB further enables the slow-charging installation to be investigated as a flexible electrical load in relation to local renewable-energy generation and future grid-service applications.

3.2. Physical Layout and Deployment

The slow-charging demonstrator is physically installed in the parking area of the DTU Risø/SYSLAB facility. The charging points are arranged in three clusters along the parking spaces, with the associated electrical connections and communication infrastructure integrated into the existing site installation. The figures below present the deployed chargers, their position at the site, and the cluster arrangement used for the demonstration activities.

The installation comprises three 32 A charging clusters: EVSE 15 and EVSE 16, each supplying three Amina chargers, and EVSE 13, supplying one Zaptec, one NextBlue (replacing the Fronius originally planned) and one Amina charger. The clusters are connected to the local low-voltage system together with the site renewable-energy interfaces and energy-metering infrastructure.

WP 7 – Nordic Europe demo: part 1 (slow chargers)

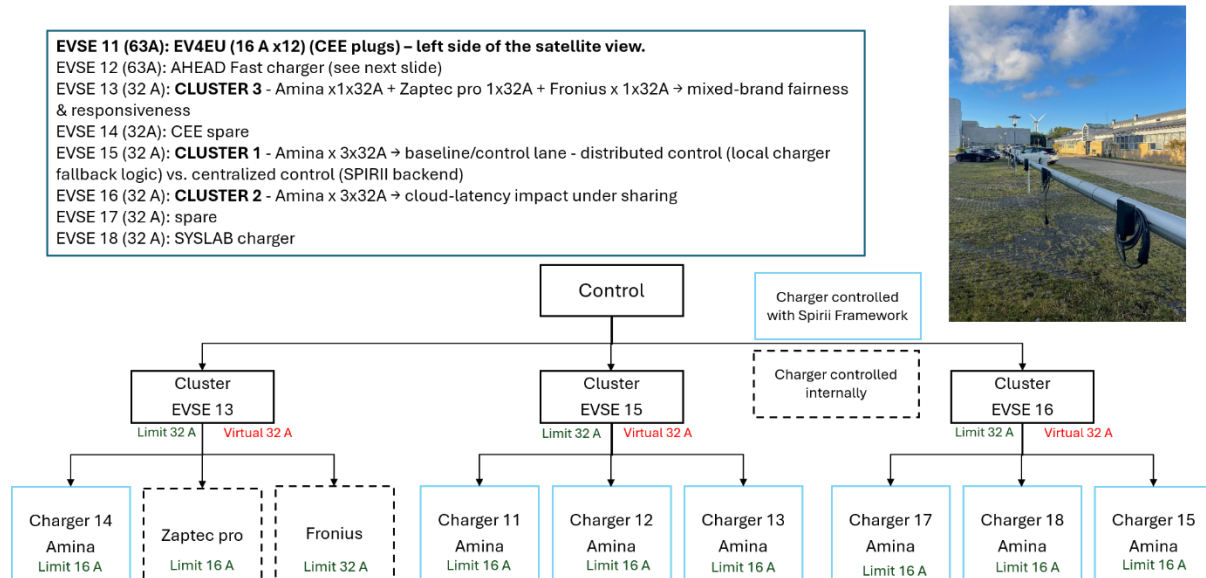


Figure 3. Cluster layout slow charging demonstration.

3.3. System Architecture

This architecture, displayed in Figure 4, provides the basis for evaluating coordinated charging control and interoperability across homogeneous and mixed-brand charger configurations.

At the communication level, the chargers are integrated with the Spirii backend platform through OCPP 1.6J-based communication. Spirii provides the interface for operational monitoring, charging-session management and application of charging-current limits. For Zaptec, the present implementation uses a cloud-mediated OCPP connection, while native OCPP integration is planned for future operation.

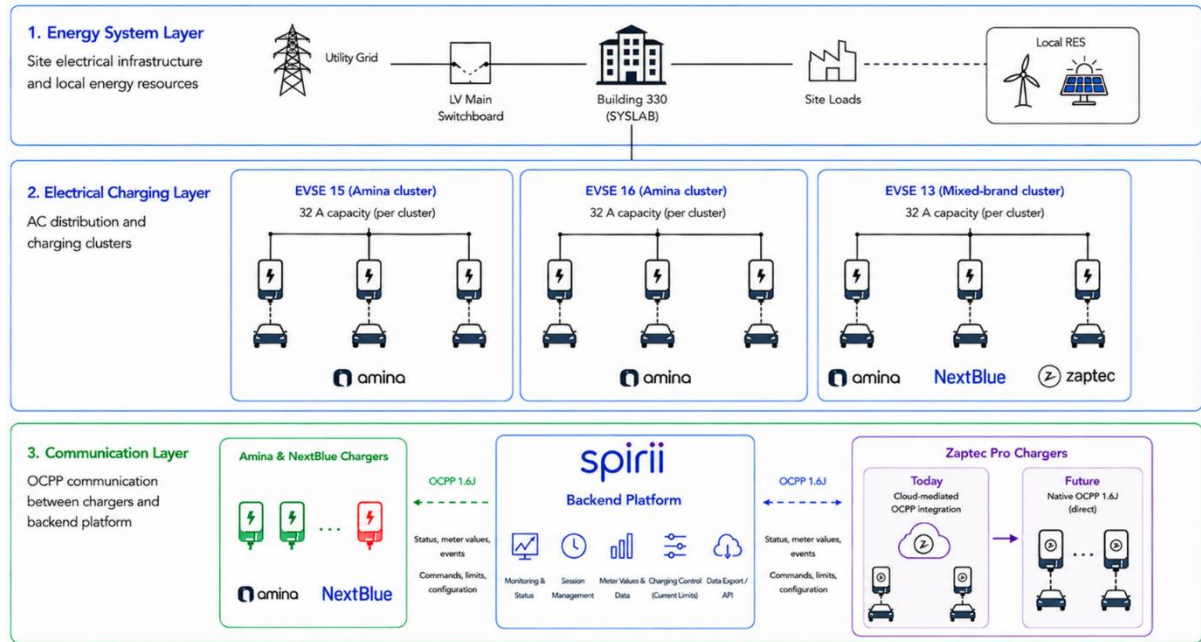


Figure 4. System architecture. Layer 2 and 3 have been specifically developed as part of the AHEAD project.

Figure 5 shows the sequence diagram, illustrating the interaction between the DTU framework, the SPIRii testing framework API, the SPIRii backend CSMS, and the charge point (EVSE). First, the DTU framework authenticates with the SPIRii API using a bearer token. Then, it retrieves the current state and power measurements via OCPP. Based on the measured power $P_i(k)$ in W, the local algorithm computes a current limit $I_i^{max}(k)$ in A and sends it to the SPIRii API using the set_limit request. SPIRii translates this request into OCPP SetChargingProfile commands, which the EVSE enforces locally. The EVSE reports measurements and status via MeterValues messages, which are passed back to the DTU framework as updated output $y(k + 1)$. Finally, the limit can be removed using the clear-limit request, and the system continues operating with periodic telemetry updates.

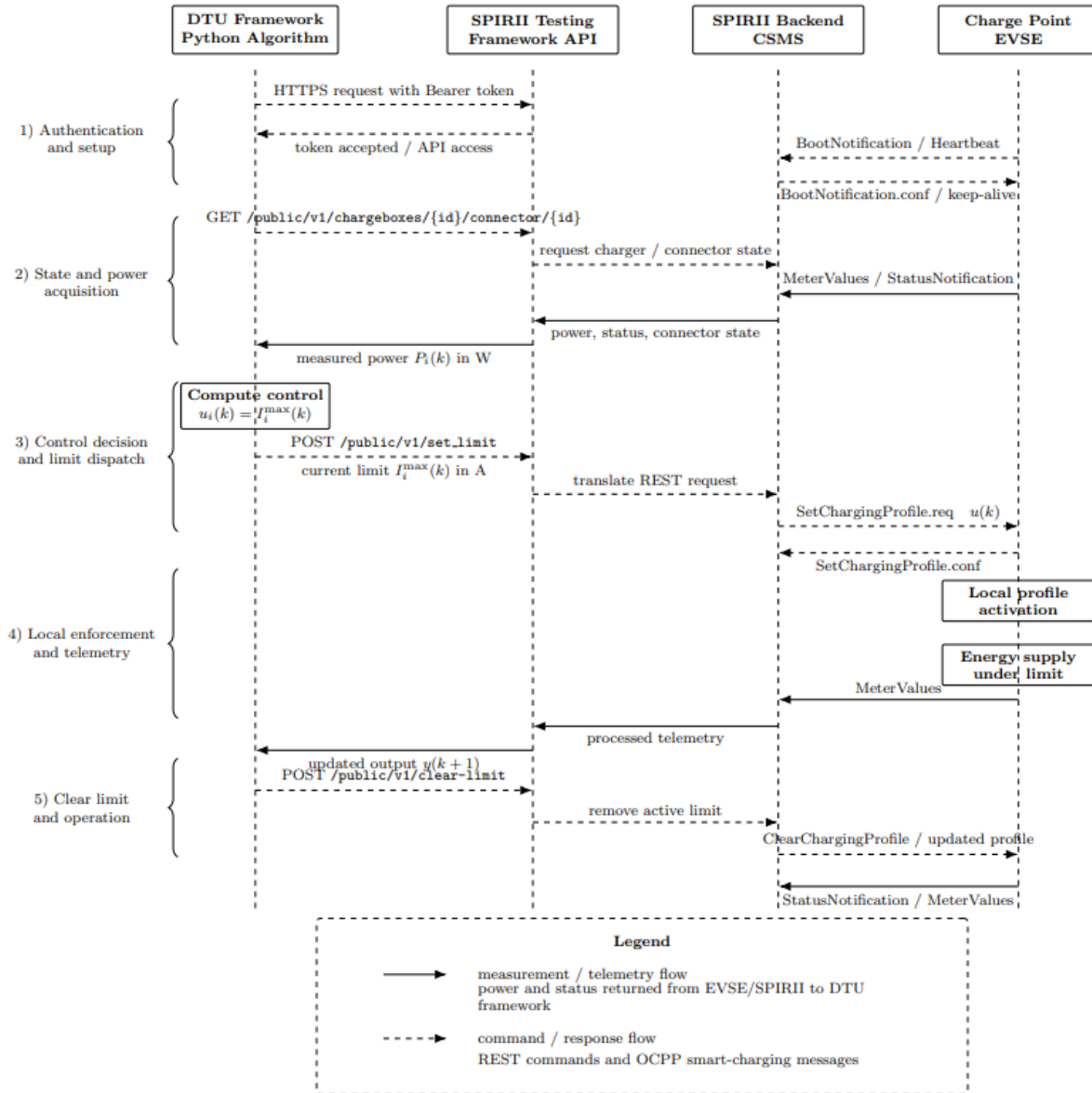


Figure 5. SPIR-II Specific Message-Driven Control Execution.

4. FAST CHARGING DEMONSTRATION

4.1. Implemented System Overview

The fast-charging installation has been designed to showcase advanced power management, battery-buffered operation and grid-support capabilities for high-power DC charging systems. This setup simulates a realistic fast-charging hub scenario by integrating multiple energy sources and implementing control strategies for peak shaving, load optimization and reduction of grid congestion. Figure 6 provides the layout of the pilot.

The configuration includes:

- 150 kW DC KEMPOWER charger.
- 325 kWh BESS from PIXII.
- 43 kW grid connection.
- 30 kW of RES (wind and solar power) connection.

These components are coordinated through an EMS that dynamically allocates power between the grid, the BESS, the RES and connected electric vehicles based on charging demand, the state of charge and grid constraints. This enables continuous assessment of system flexibility, control reliability and communication interoperability among the charger, battery and backend systems.

Extensive monitoring at the DC link and grid interface provides high-resolution data for model validation and algorithm tuning, while OCPP-based control ensures vendor-neutral interoperability.

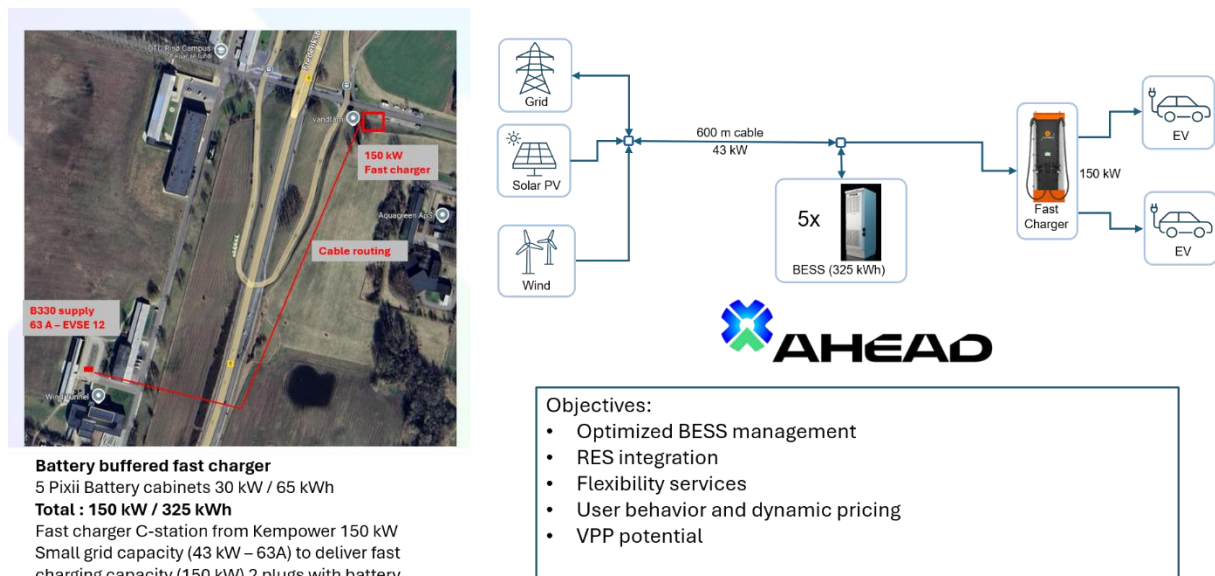


Figure 6. Cluster layout fast charging demonstration.

The installation has been completed in September 2026. The fast charger and the 5 battery packs are reported in Figure 6.



Figure 7. Fast charging demo site with the installation completed.

4.2. System Architecture

The demonstration was initially planned in three phases. The planned phases are revised according to the implementations and studies that have been conducted during the first 2 years of the AHEAD project. Figure 8 provides the first version of the architecture: it requires the local controller and modbus mapping to BESS and measurement devices for measurements. The local controller monitors production of renewable energy sources, battery SOC, EV charging demand and power exchange with the grid. The control logic implemented in the local controller will control charge/discharge of the battery.

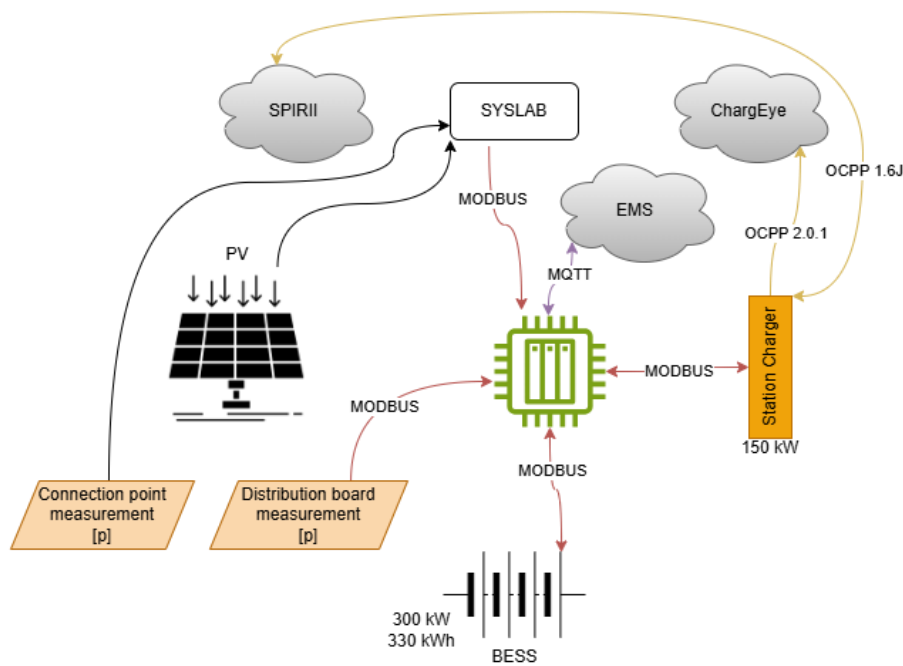


Figure 8. EMS first phase architecture.

In the second phase, the local controller is expected to receive real-time/scheduled flexibility commands from SYSLAB EMS. The local controller manages the connected resources based on the flexibility received. In this phase, the local controller is connected to the cloud EMS primarily for data archiving. Figure 9 shows the second phase of the architecture.

In the third phase, shown in Figure 10, the focus is on implementing SYSLAB EMS for data gathering and high-level control logic, which is connected via MQTT to the local controller. In this phase, decision-making about the controllable resources is based on optimising control variables. The local controller manages the connected resources based on the control variable values received from the SYSLAB EMS.

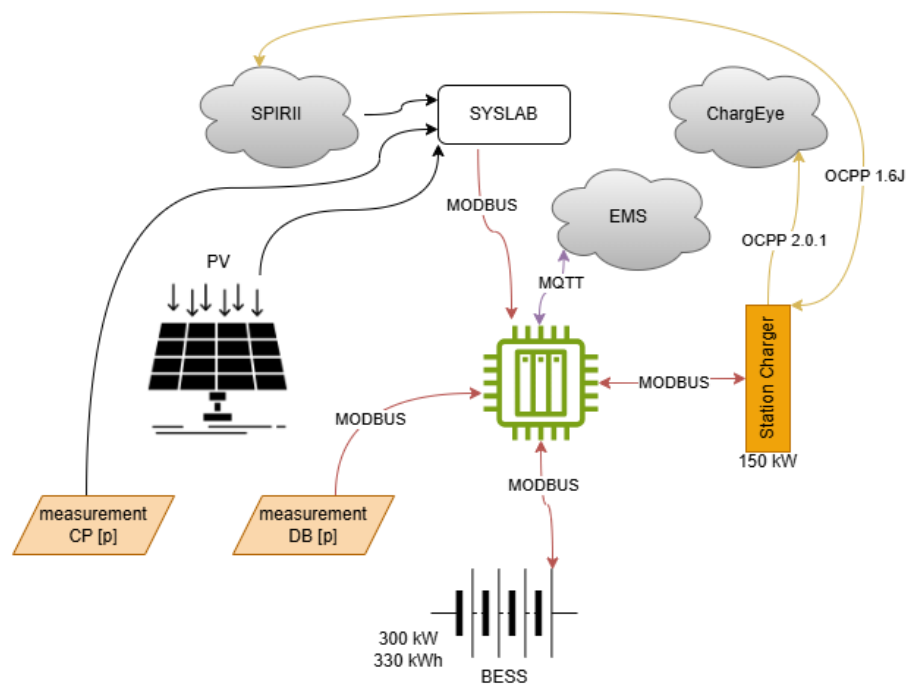


Figure 9. EMS second phase architecture.

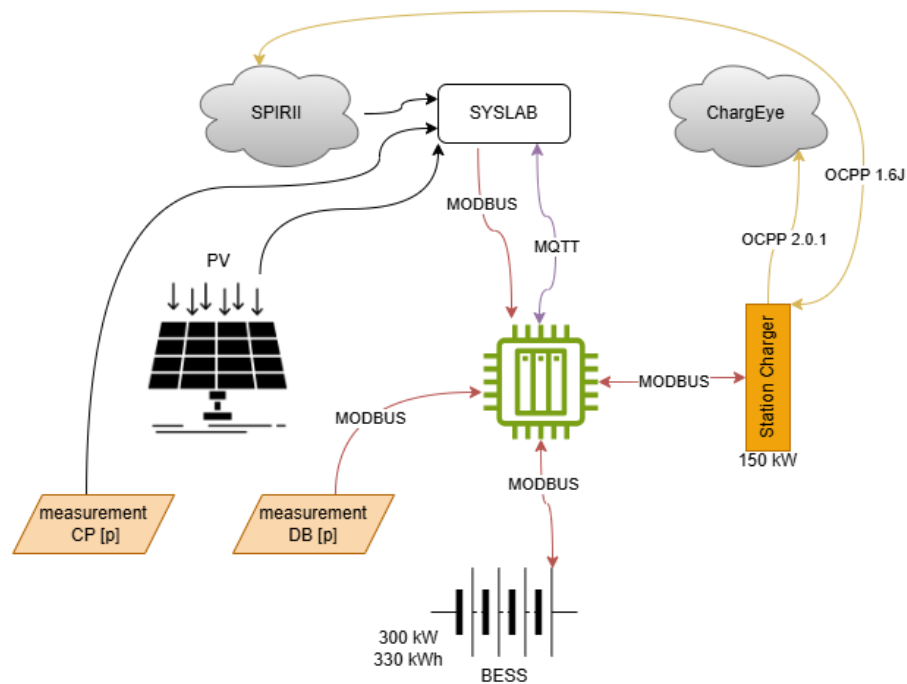


Figure 10. EMS third phase architecture.

5. USER INTERFACE AND ACCESSIBILITY

EV drivers can charge at the DTU Campus chargers using the Spirii Go charging app; major information is provided in the app screenshots in Figure 11. In the first figure, we can see the location, the number of available chargers (4 out of 7 when the picture was taken), the expected charging power of 11-22 kW and the cost of charging, which in the figure equals “Free of charge”. Upon clicking on the “Charge here”, the user enters the second screen where we can see details of the available (as well as charging) chargers, and by clicking on the charger he wants to select, he is moved to the third screen where it is possible to start charging and select the payment method.

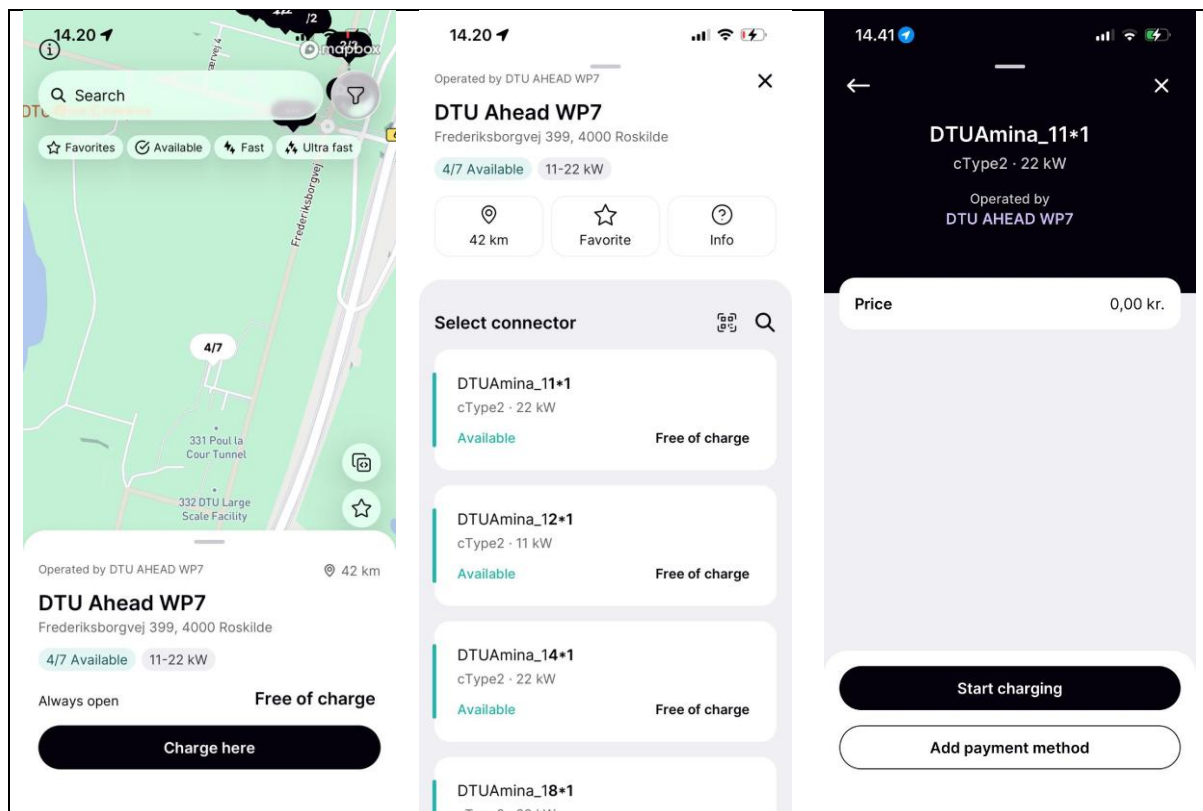


Figure 11. Spirii Go app AHEAD DTU chargers.

From the management side of the chargers, DTU is currently the Charging Point Operator (CPO) installed at the Campus. Through the Spirii platform “Connect,” whose main page is shown in Figure 12, DTU has access to various online data on the chargers. These include the following product features²: Connector status, dynamic load management, flexible and dynamic pricing, location management, set rules and activation times for chargers, autocharge and Plug&Charge, charge key management, customer management and onboarding,

² [Spirii Product Features link](#)

customizable fees, export data (generate CSV with historical data), insights dashboard, remote management, service notifications, vouchers and user groups.

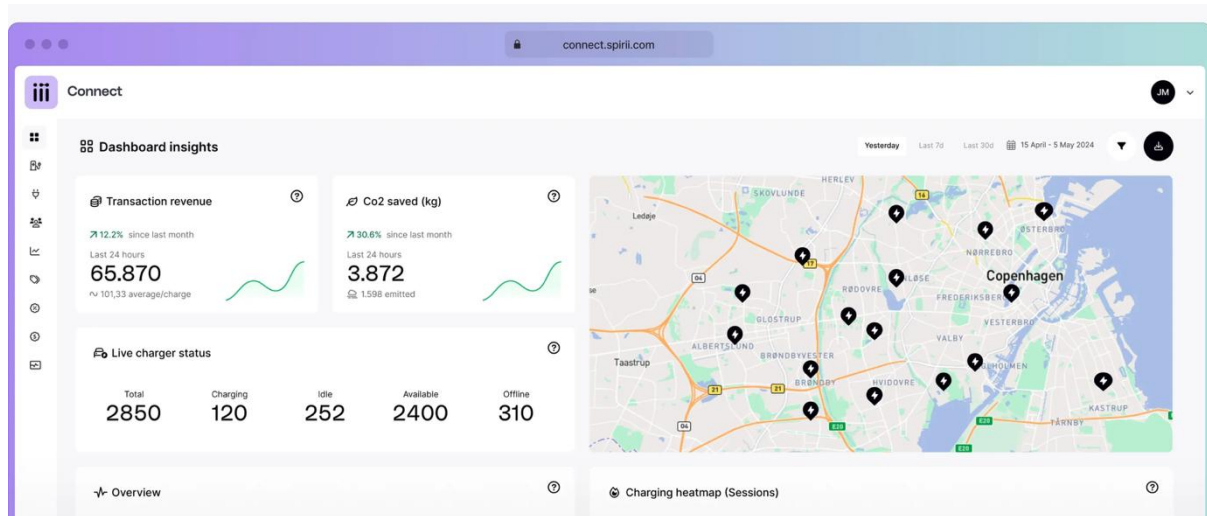


Figure 12. Spirii Connect ³

³ [Spirii Connect link](#)

6. DATA ACQUISITION AND STORAGE

The EV Charger Power Dashboard is a real-time web application that monitors the EV charging infrastructure at the Risø DTU campus. It provides operators with a live overview of charger power and status, phase-level measurements, and a 4-hour forecast of electricity spot prices and grid CO₂ emissions. The dashboard is accessible via a web interface at <https://evbe.elektro.dtu.dk/> (additional details of the web interface are provided in the next section).

The system is implemented as two independent processes running on a server located in the demilitarized zone (DMZ): a data pipeline, which stores measurements in EnergyData.dk, and a dashboard application, which retrieves these data and renders the visualizations in a web browser. An overview of the system architecture is provided in Figure 13.

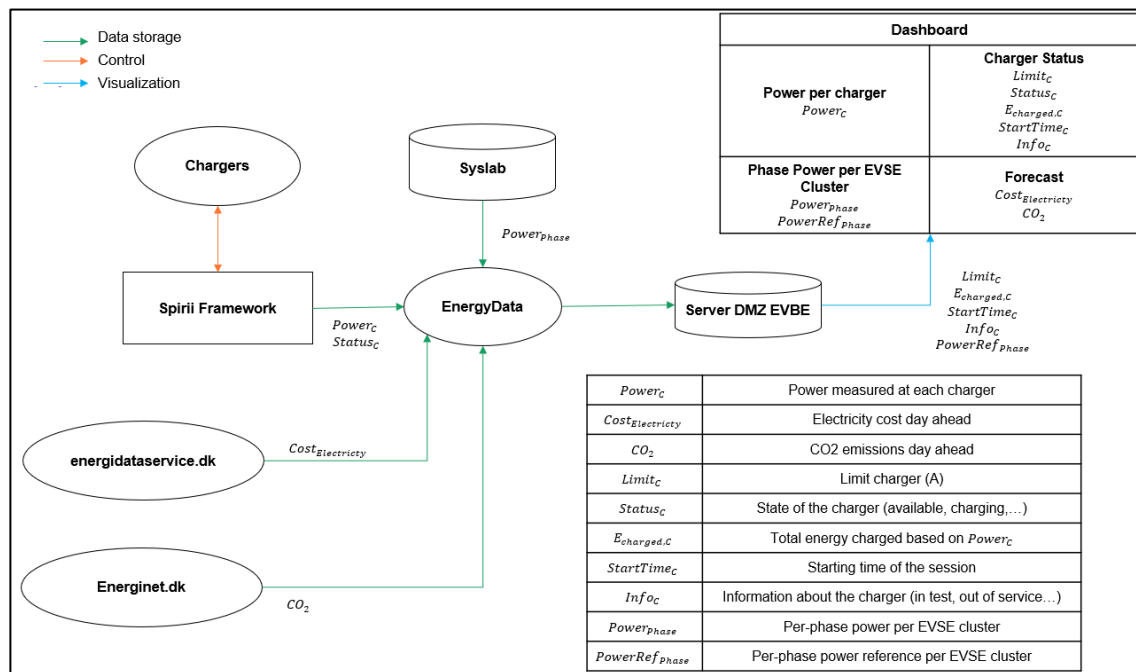


Figure 13. Overview of the EV charging system architecture. Data flows (green), control signals (orange), and visualization paths (blue) are shown, with key variables indicated along each connection.

EnergyData.dk acts as the central data repository, aggregating heterogeneous data streams into a unified storage platform. Four primary sources feed into this database:

- The Spirii Framework provides charger-level operational data, including the active power P_C (kW) and the charger status $Status_C$, recorded with a sampling interval of 5 s.

- The DTU Risø Syslab system supplies phase-resolved power measurements, denoted P_ϕ (kW), at the EVSE cluster level, with a temporal resolution of 1 second.
- Day-ahead electricity spot prices, denoted $Cost_{\text{electricity}}$ (DKK/MWh), are obtained from Energidataservice and updated daily at 16:00 with a 15-minute resolution.
- Grid CO₂ emissions, denoted CO_2 (g/kWh), are provided by Energinet and updated daily at 16:00 with an hourly resolution.

The following variables are computed at runtime by the server from the data stored in Energy-Data.dk:

- $I_{\text{limit},c}$: Charging current limit per connector c (A), currently set to 16 A in the dashboard, but configurable within the control logic.
- $E_{\text{charged},c}$: Energy delivered during the current charging session of charger c (kWh), computed by integrating the active power signal over time when $Status_c = \text{Charging}$:

$$E_{\text{charged},c} = \sum_{i=1}^N P_{c,i} \Delta t_i$$

where $P_{c,i}$ is the measured active power of charger c at sample i , expressed in kW, and Δt_i is the time interval between two consecutive samples, expressed in hours:

$$\Delta t_i = \frac{t_i - t_{i-1}}{3600}$$

Therefore, since power is expressed in kW and time is expressed in hours, the resulting energy is obtained in kWh.

- $StartTime_c$: Timestamp corresponding to the latest transition of the charger status from “Available” to “Charging”.
- $P_{\text{ref},\phi}$: Per-phase reference power (kW), computed from the phase voltage and the current limit as:

$$P_{\text{ref},\phi} = \frac{I_{\text{limit}} V_\phi}{1000}$$

For a current limit of 32 A and a phase voltage of 230 V, this gives:

$$P_{\text{ref},\phi} = \frac{32 \cdot 230}{1000} = 7.36 \text{ kW}$$

- $Info_c$: Additional information about the charger, indicating its operational condition, for example under test or out of service.

7. VISUALIZATION OF EV CHARGING AND ENERGY SYSTEM SIGNALS

Visualization of EV charging demo in Risø, is structured into four panels arranged in a 2×2 grid, providing a comprehensive overview of the EV charging system, shown in Figure 14.

EV Charger Power Dashboard

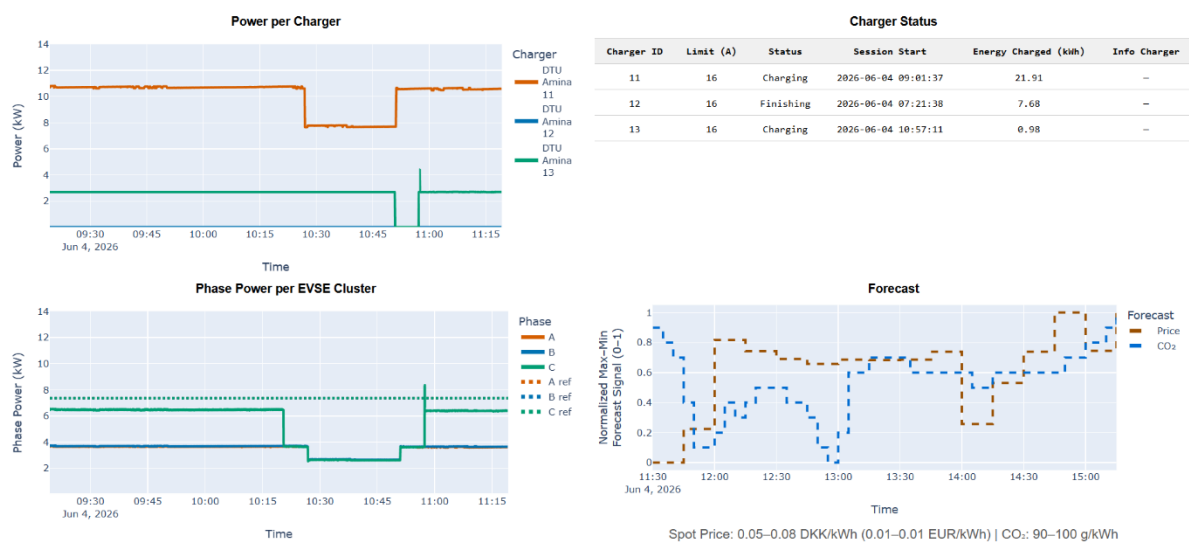


Figure 14. EV charger power dashboard interface showing real-time charger power, charger status indicators, aggregated phase power at the EVSE cluster level, and short-term forecasts of electricity price and CO₂ emissions.

Two header controls apply to all panels simultaneously:

- **EVSE cluster selector:** switches between clusters 13, 15, and 16, updating all panels accordingly. It can be preselected using the URL parameter `?evse=<id>`.
- **Time window:** defines the look-back period for the live plots, namely 1 min, 5 min, 30 min, 1 h, 2 h, or 4 h, configurable via the URL parameter `?window=<minutes>`.

The three real-time panels, namely power, status, and phase power, are refreshed every 5 seconds, while the forecast panel is updated every minute.

7.1 Power per Charger (top left)

This panel displays the time series of active power P_c (kW) for each charger in the selected EVSE cluster. The power is set to zero when the charger is not in the charging state.

7.2 Charger Status (top right)

This panel provides a tabular overview of the current operational state of each charger, including charger ID, current limit, status, session start time, delivered energy, and additional information.

7.3 Phase Power per EVSE Cluster (bottom left)

This panel shows the aggregated power (kW) across phases A, B, and C for the selected EVSE cluster. A reference line at 7.36 kW indicates the maximum power per phase corresponding to a 32 A limit.

7.4 Forecast (bottom right)

This panel presents a normalized overlay of electricity price and CO₂ emissions over a 4-hour horizon, enabling identification of cost-efficient and low-carbon charging periods.

The display window is aligned with the temporal resolution of the data by starting at the most recent 15-minute boundary prior to the current time and extending over a forward horizon of 4 hours.

Since the two signals have different units and magnitudes, each is independently normalized to the interval [0, 1]:

$$\hat{x} = \frac{x - \min(x)}{\max(x) - \min(x)}$$

If a signal is constant over the considered window, i.e., $\max(x) = \min(x)$, the normalized value is set to 0.5.

Summary statistics displayed below the plot report the range of electricity prices in DKK/kWh and EUR/kWh, using a conversion rate of 7.46038 DKK/EUR, as well as the range of CO₂ emissions in g/kWh.

8. CONCLUSION

This deliverable has presented the commissioning and start-up activities of the Nordic demonstration sites developed within Task 7.2 of the AHEAD project. Building upon the design specifications and test-case definitions of Task 7.1, the work reported here marks the successful transition from conceptual system design to the realization of a fully operational experimental platform at the DTU Risø Campus.

Both the slow AC charging and fast DC charging demonstrations have been implemented, integrated, and validated within a unified system architecture that combines EV charging infrastructure, renewable energy sources, battery energy storage systems, and advanced communication platforms. The slow-charging demonstrator provides a flexible test environment for investigating aggregated EV charging loads, multi-brand interoperability, and smart charging strategies, including demand response, dynamic pricing, and AI-based coordination. In parallel, the fast-charging demonstrator showcases high-power charging supported by battery buffering and renewable integration, enabling advanced use cases such as peak shaving, grid support, and flexibility provision even under limited grid capacity.

A key achievement of Task 7.2 is the establishment of a robust data acquisition and monitoring framework, capable of collecting high-resolution operational data across all system components. Combined with the developed visualization tools and user interfaces, this enables real-time system supervision, detailed performance analysis, and seamless user interaction.

Overall, the commissioning process has verified the correct installation, communication, and controllability of all assets, while the start-up phase has demonstrated stable and continuous operation of the system under real-world conditions.

In conclusion, Task 7.2 has successfully delivered a comprehensive and operational demonstration infrastructure that meets the requirements for the execution of the defined test cases. The established platform provides a solid foundation for the next phases of the project (Tasks 7.3 and 7.4), where advanced control strategies, AI-based methods, and flexibility services will be experimentally validated. More precisely, in T7.3 the fast charger solution will be tested along Use uses cases in table 2. Whereas in T7.4 the tests with the slow chargers will be conducted, developing the use cases in Table 1.

BIBLIOGRAPHY

- [1] L. Vanhaverbeke, D. Verbist, G. Barrera and M. Csukas, “Consumer Monitor 2023 European Alternative Fuels Observatory European Aggregated Report,” Publications Office of the European Union, Brussels, 2024.
- [2] L. Vanhaverbeke, D. Verbist, G. Barrera, M. Csukas and R. Jüriado, “Consumer Monitor 2023 European Alternative Fuels Observatory Country Report Italy,” Publications Office of the European Union, Brussels, 2024.
- [3] L. Vanhaverbeke, D. Verbist, G. Barrera, M. Csukas and R. Jüriado, “Consumer Monitor 2023 European Alternative Fuels Observatory Country Report Denmark,” Publications Office of the European Union, Brussels, 2024.
- [4] L. Vanhaverbeke, D. Verbist, G. Barrera, M. Csukas and R. Jüriado, “Consumer Monitor 2023 European Alternative Fuels Observatory Country Report Slovenia,” Publications office of the European Union, Brussels, 2024.
- [5] FDEL; FDM; DTU; IDA, “Elbiler og ladeinfrastruktur 2022 - Analyse foretaget i et samarbejde mellem FDEL, FDM, DTU og IDA Tabelrapport,” IDA, Copenhagen, 2022.
- [6] Energy & Strategy Group of Politecnico di Milano, “Smart Mobility Short Report 2023 - La «via italiana» per la decarbonizzazione dei trasporti nel nuovo scenario geo-politico internazionale,” Politecnico di Milano, 2023.
- [7] T. Unterluggauer, “Urban Electric Vehicle Charging Infrastructure : Planning, Grid Impact and Grid Integration,” Technical University of Denmark, Lyngby, 2024.
- [8] “European Alternative Fules Observatory (EAFO),” European Commission, [Online]. Available: <https://alternative-fuels-observatory.ec.europa.eu/>. [Accessed 2024].
- [9] M. Secchi, A. Ivanova and J. Eichman, “EV mobility diffusion and future perspectives in the EU: results from the FLOW project,” in *7th E-Mobility Power System Integration Symposium (EMOB 2023)*, 2023.
- [10] M. Rajon Bernard, N. Michael, S. Wappelhorst and D. Hall, “A Review of the AFIR Proposal: How Much Power Output is Needed for Public Charging Infrastructure in the EU?,” 2022.

-
- [11] Motus-E, “Il Futuro della Mobilità Elettrica in Italia @ 2035,” 2024.
- [12] M. Secchi and P. B. Andersen, “FLOW's D1.2 - Baseline: Scenarios and definitions,” 2023.
- [13] H. Morais, I. Cavalcante, A. R. Nunes, L. Calearo, A. Malkova, C. Ziras, M. Brito, J. Mateus, S. Matias, K. Michos, P. Pediaditis, A. Lekidis, I. Mendek and M. Zajic, “EV4EU's D1.1,” 2023.
- [14] Artemis Technologies, 2024. [Online]. Available: <https://www.artemistechnologies.co.uk/charging/>. [Accessed 7 October 2024].
- [15] Wärtsilä, “Vessel Charging Solutions,” 2024. [Online]. Available: <https://www.wartsila.com/marine/products/ship-electrification-solutions/shore-power/charging>. [Accessed 7 October 2024].
- [16] Future Bridge, “Standardized electric charging connectors for marine vessels,” 2024. [Online]. Available: <https://netzero-events.com/standardizing-electric-charging-connectors-for-marine-vessels/>. [Accessed 7 October 2024].
- [17] Kempower, “Charging Forward in Maritime Transport: Electrifying Ports, Ships, and Boats,” 2024. [Online]. Available: <https://kempower.com/stories/kempower-electrifies-ports-ships-and-boats-with-plug-and-evoy/>. [Accessed 7 October 2024].
- [18] ABB, “Electric passenger ferries: Future charging infrastructure,” 2024. [Online]. [Accessed 7 October 2024].
- [19] Automóvel Club de Portugal (ACP), “Estudo Mobilidade Elétrica em Portugal,” March 2023. [Online]. Available: https://revista.acp.pt/estudo_mob_eletrica23/. [Accessed 7 October 2024].
- [20] Teknisk Ukeblad Media AS, “Fjord1: Velger Tyrkia som byggested for selvkjørende ferger,” 2024. [Online]. Available: <https://www.tu.no/artikler/fjord1-velger-tyrkia-som-byggested-for-autonome-ferger/544260>. [Accessed 11 November 2024].
- [21] J. Pratt, “Battery Electric and Hybrid Vessels in Norway and Denmark: Ampere, Vision, and HH Ferries,” 15 December 2016. [Online]. Available: <https://www.maritime.dot.gov/sites/marad.dot.gov/files/docs/innovation->

research/meta/3381/sandia-battery-vessels-marad-workshop.pdf. [Accessed 18 September 2024].

- [22] A. Rogers, "Battery Electric Ferry: The Ampere in Norway," Electric Power Research Institute, 2015.
- [23] Directorate-General for Mobility and Transport, "EU classification of vehicle types," EU commission.
- [24] Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, "Vehicle categories," EU commission.
- [25] European Environment Agency, "Heavy duty vehicles".
- [26] European Parliament, "Review of the CO2 emission standards for heavy-duty vehicles".
- [27] International Energy Agency, "Tracking Electrification".
- [28] TransportPolicy, "EU: Vehicle Definitions".
- [29] National Centre for Charging Infrastructure Germany, " Charging infrastructure for commercial vehicles," [Online]. Available: <https://nationale-leitstelle.de/en/charging-infrastructure-for-commercial-vehicles/>. [Accessed 5 November 2024].
- [30] A. Thingvad, P. B. Andersen, T. Unterluggauer, C. Træholt and M. Marinelli, "Electrification of personal vehicle travels in cities - Quantifying the public charging demand," *eTransportation*, vol. 9, p. 100125, 2021.
- [31] C. Ziras, M. Thingvad, T. Fog, G. Yousefi and T. Weckesser, "An empirical analysis of electric vehicle charging behavior based on real Danish residential charging data," *Electric Power Systems Research*, vol. 234, p. 110556, 2024.
- [32] DNV GL Group Technology and Research, "ReCharge: Analysis of charging- and shore power infrastructure in Norwegian ports," Trondheim, 2017.
- [33] M. Amaral, N. Amaro and P. Arsénio, "Methodology for Assessing Power Needs for Onshore Power Supply in Maritime Ports," *Sustainability*, vol. 15, no. 24, p. 16670, 2023.
- [34] Energynautics GmbH, "International Hybrid Power Systems Workshop: Power System in Madeira & Porto Santo," 26-27 April 2022. [Online]. Available:

<https://hybridpowersystems.org/Madeira2022/power-system-madeira-porto-santo/>.
[Accessed 13 November 2024].

[35] Norwegian Electric Vehicle Association, "Norwegian EV Driver Survey 2023," Oslo, 2023.

[36] M. Rajon Bernard, "European Union Alternative Fuel Infrastructure Regulation (AFIR)," INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION, 2023.

9. ANNEX

9.1. Supporting Technical Documentation

AMINA Charger



Designed by amina

Technical specifications

General	Dimensions: 264mm x 112mm x 89mm Operating temperature: -30°C to +40°C
Weight	1,0 kg w/o cable 2,5 kg w/ 6m 3-phase 20A cable 3,5 kg w/ 6m 3-phase 32A cable
Power grid and voltages	TN, IT and TT 230V/400V AC 3-phase w/ Neutral 230V AC 1-phase
Charging Cable	Fixed cable included (replaceable) Type 2 plug (EN 62196) 6m 3-phase 20A/32A
Charging power 20A variant	3-phase output: 3,7 – 13,8 kW 1-phase output: 1,4 – 4,6 kW
Charging power 32A variant	3-phase output: 3,7 – 22,0 kW 1-phase output: 1,4 – 7,4 kW
Energy-meter	1 or 3-phase ±2 % accuracy
Communications interface	Bluetooth LE, and Zigbee 4G - LTE Cat 1 bis WiFi - 2.4 GHz & 5 GHz - IEEE 802.11a/b/g/n/ac/ax RFID / NFC – ISO/IEC 14443 A/B
Frequency utilization	13.56 MHz: < 42dBuA/m 2400 - 2483,5 MHz: <20dBm 5150 - 5350 MHz: <18dBm 5470 - 5725 MHz: <18dBm LTE bands B1/3/7/8/20/28: Class 3
OCPP	Local OCPP 1.6j with enhanced security Hardware ready for OCPP 2.0.1
Security features	Hardware Security and cryptography module TLS 1.3
Degree of protection	Resistant to impact, dust, water IP54: indoor and outdoor use IK08: impact protection UV-resistant
Electrical protection	Protection class I Overvoltage category III (4 kV)
Integrated RCD	RDC-DD (6mA DC)
Installation	Circuit breaker (max 40A) RCD (max 30mA AC) 4 – 16mm cable diameter Single core or stranded wires 1,5 – 6mm² w/ ferrules 1,5 – 10mm² w/o ferrules
Regulations and standards ①	RED 2014/53/EU RoHS 2011/65/EU

① The full text of the EU Declaration of Conformity (DoC) is available at download.aminacharging.com

Fronius Charger

Technical data

			Wattpilot 2.0							
			Go 11 J 2.0		Go 22 J 2.0		Home 11 J 2.0		Home 22 J 2.0	
Input data			1-phase	3-phase	1-phase	3-phase	1-phase	3-phase	1-phase	3-phase
	Maximum charging power	kW	3,68	11	7,36	22	3,68	11	7,36	22
	Grid configurations		TT / TN / IT							
	Mains connection		CEE16 30 cm incl. neutral conductor		CEE32 30 cm incl. neutral conductor		5-pin cable 180 cm incl. neutral conductor		5-pin cable 180 cm incl. neutral conductor	
	Optional adapters		CEE32 (red) / CEE-Cara 16 A (camping plug blue) / safety plug 16A		CEE16 (red) / CEE-Cara 16A (camping plug blue) / safety plug 16 A					
			1-phase	3-phase	1-phase	3-phase	1-phase	3-phase	1-phase	3-phase
	Nominal voltage	V	230/240	400/415	230/240	400/415	230/240	400/415	230/240	400/415
	Nominal current (configurable)	A	6–16 A 1-phase or 3-phase		6–32 A 1-phase or 3-phase		6–16 A 1-phase or 3-phase		6–32 A 1-phase or 3-phase	
	Mains frequency	Hz	50		50		50		50	
	Charging socket		Infrastructure-side Type 2 socket with mechanical locking							
Residual current device ¹		20 mA AC, 6 mA DC integrated in device								
Cable cross-section, supply line	mm²	Minimum 2.5		Minimum 6		Minimum 2.5		Minimum 6		

General data	PV optimization ²		Dynamic PV surplus charging with 1.38–11 kW (at 230/400 V, automatic 1-/3-phase switching)	Dynamic PV surplus charging with 1.38–22 kW (at 230/400 V) (automatic 1-/3-phase switching)	Dynamic PV surplus charging with 1.38–11 kW (at 230/400 V, automatic 1-/3-phase switching)	Dynamic PV surplus charging with 1.38–22 kW (at 230/400 V) (automatic 1-/3-phase switching)
	Charging mode		Mode 2 as per IEC 61851-1 AC charging	Mode 2 as per IEC 61851-1 AC charging	Mode 3 as per IEC 61851-1 AC charging	Mode 3 as per IEC 61851-1 AC charging
	Network connection ³		WLAN 802.11 b/g/n			
	Authentication		RFID			
	Communication protocols		OCPP 1.6 J			
	Dynamic Load Balancing		Integrated (unlimited number of charging stations)			
	Usage ⁴		Indoors and outdoors			
	Type of installation		Suspended upright			
	Safety class		IP 65	IP 65	IP 65	IP 65
	Standards/Guidelines		EN IEC 61851-1 EN 62752 EN 62196	EN IEC 61851-1 EN 62752 EN 62197	EN IEC 61851-1 EN 62196	EN IEC 61851-1 EN 62197
	Dimensions (H x W x D)	mm	287 x 155 x 109			
	Weight	kg	1,6	1,8	1,8	2,3
	Average temperature over 24 h	°C	max. 35	max. 35	max. 35	max. 35
	Ambient Temperature ⁵	°C	-25 to +40 (without direct sunlight)			
	Humidity	%	5 - 95	5 - 95	5 - 95	5 - 95
	Altitude above sea level	m	0 - 2000	0 - 2000	0 - 2000	0 - 2000
Impact resistance		IK08	IK08	IK08	IK08	

Zaptec charger

Technical Specifications - ZAPTEC Pro

ZAPTEC Pro is an alternating current wall or column-mounted charging station in accordance with IEC 61851-1, EVSE mode 3.

Dimensions and weight

H: 392 mm W: 258 mm D: 112 mm
Weight: approx. 5 kg (including backplate)

Installation circuit

Max. 63A serial fuse on installation circuit for charging stations.

Backplate connection box

Cable cross section 2.5–10 mm²
Cable diameter 10–20mm²

Installation network, Voltages

TN, IT and TT
230VAC ±10%
400VAC ±10%

Max. current and charging output

7.36kW* at 32A/1-phase
22kW* at 32A/3-phase (applicable to TN networks only)
5W at standby

Fuses

Built-in 3 x 40A fuses type C

Charging point

EC 62196-2 Type 2 Female with integrated self-closing cover

Earth fault protection

Built-in type B RCD
Calibration and a self-test are carried out before the start of every charging cycle. RCD can be automatically reset by disconnecting from the charging connector.

Integrated Power Meter

MID tested and calibrated (EN 50470).

Theft protection

The front cover of the ZAPTEC Pro can only be opened using a special tool. The charging cable can be locked permanently to the charging station.

Load balancing

Together with other ZAPTEC Pro charging stations, available power in the installation will be distributed automatically between the devices and phases.

Phase balancing

The charging station will dynamically select any single phase or 3-phase in a system with other ZAPTEC Pro charging stations, depending on the available power.

Communications interface and cloud connection/network

4G LTE-M1 (subscription required)
Wi-Fi 2.4 GHz, IEEE 802.11 b/g/n (channels 1-11)
Powerline (PLC) – HomePlug Green PHY®, 10 Mbit/s

Identification and configuration

Bluetooth Low Energy (BLE 4.1)
RFID/NFC reader – Mifare Classic, Type A
PLC for vehicle interface for future services as defined by ISO 15118

Standards and approvals

CE compliance in accordance with the Radio Equipment Directive 2014/53/EU and RoHS Directive 2011/65/EU, and compliance with IEC 61851-1 (TUV SÜD) and IEC 61851-22

Temperature range

–30°C to +50°C

Degree of protection

IP54, indoor and outdoor use
IK10 impact protection
UL94 5VB flammability rating
UV resistant

Electrical protection

Protection class II (4kV AC and 6kV impulse, insulation)
Overvoltage category III (4kV)

Integration services

Third-party integration alternatives
(API, Webhooks)
OCPP 1.6J
Message subscription

* 32A is available but may be restricted by the condition of the vehicle's battery and temperature increases at the charging station.

See the charging consumption in the administration system or the app

4G LTE-M
Internet connection

Simple identification with charging card

Lock the charging cable to the charging station

Self-closing cover



zaptec.com

© ZAPTEC Charger AS 05.2020. All rights reserved.

KEMPOWER



kempower.com

Product code interpretation

C801•P160•NC•5•C•S•D2•C0 Kempower Station Charger C800 single cabinet • 200 kW charging power • 1 x CCS2 vehicle connector • charging cable length 5 m • nominal charging cable current 200 A • standard user interface • up to 2 dynamic outputs • unbranded

Item	Code	Description
Product type	C801	Kempower Station Charger C800 single cabinet
	C802	Kempower Station Charger C800 double cabinet
Charging power*	P160	200 kW (4 modules)
	P320	400 kW (8 modules)
	N	When in front of the vehicle connector type, indicates that there is only one connector
Vehicle connector type	C	CCS2
	CC	2 X CCS2
	CCA	2 X CCS2 & Type 2 AC
	CD	CCS2 & CHAdeMO
	CDA	CCS2 & CHAdeMO & Type 2 AC
Charging cable length	5	5 m
	7	7 m
Nominal charging cable current	B	125 A (CHAdeMO)
	C	200 A (CCS2)
	D	250 A (CCS2)
	E	300 A/500 A** (CCS2)
User interface and payment	S	Standard user interface
	O	Payter Apollo: Contactless payment with online PIN entry and verification
	P	Payter P66: Only contactless payments, no strong customer authentication (SCA) possibility
Power distribution modules	D2	Up to 2 dynamic outputs
Branding options	C0	Unbranded: roof and base in black color, no stickers
	Cn	Branded: number (n) indicates branding, e.g. C8

* Standard operation. See Power performance table for details.

** With 300 A charging cables:
500 A (max. 10 min) in +25 °C. Requires at least 3 output terminals and a specific hardware configuration.
375 A continuous in +25 °C. Requires at least 2 output terminals and a specific hardware configuration.