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Performance analysis and optimization recommendations

Deliverable D9.4

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Deliverable D9.4

PERFORMANCE ANALYSIS AND OMPTIMISATION RECOMMENDATIONS

Organisation: EDM

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DELIVERABLE 9.4 – VERSION 3
WORK PACKAGE N° 9

Nature of the deliverable		
R	Document, report (excluding the periodic and final reports)	x
DEC	Demonstrator, pilot, prototype, plan designs	
DEM	Websites, patents filing, press & media actions, videos, etc.	
O	Software, technical diagram, etc.	

Dissemination level		
PU	Public	
CO	Confidential, restricted under conditions set out in Model Grant Agreement	x
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

Quality procedure

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1	26/09/2025	Ben Wafique Omar	Draft containing all contributions from partners
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More information on the project can be found at https://www.maesha.eu

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NOTATIONS, ABBREVIATIONS AND ACRONYMS

AC	Air Conditioning
aFRR	automatic Frequency Restoration Reserve
AGC	Automatic Generation Control
API	Application programming Interface
BESS	Battery Energy Storage System
C&I	Commercial and Industrial
DR	Demand Response
EMS	Energy Management System
EV	Electrical Vehicle
FCR	Frequency Containment Reserve
FMTP	Flexibility Management and Trading Platform
HMI	Human Machine Interface
IoT	Internet of Things
KPI	Key Performance Indicators
LEC	Local Energy Community
LS	Large Scale
mFRR	manual Frequency Restoration Reserve
MQTT	Message Queuing Telemetry Transport
OCPP	Open Charge Point Protocol
PLC	Programmable Logic Controller
PV	Photovoltaics
RC	Resistance-Capacitance
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SO	System Operator
SOC	State Of Charge
SS	Small Scale
UI	User Interface
VPP	Virtual Power Plant

EXECUTIVE SUMMARY

Deliverable D9.4 presents the performance analysis of the MAESHA demonstration. As explained in Deliverable D9.3, the demonstration was carried out in a simulated environment rather than through a physical deployment in Mayotte. For the rationale behind this change of scope and the context of the decision, readers are referred to D9.3. The focus of this deliverable is therefore on how the simulated demonstrations performed against predefined indicators, and what these results imply for future deployment and replication.

The analysis is organised around four Use Cases that capture key challenges of island energy systems: frequency control, reduction of consumption peaks, maximisation of renewable energy use for electric vehicle charging, and energy access through Local Energy Communities. Each Use Case was assessed using a set of Key Performance Indicators designed to quantify technical accuracy, service stability, and system value. In addition, the deliverable draws lessons on operational feasibility, scalability and regulatory or infrastructural preconditions.

For Use Case 1 (frequency control), the demonstration confirms that both small-scale and large-scale Virtual Power Plants can technically provide automatic frequency restoration reserve in an island context. The small-scale VPP, controlling aggregated PV curtailment, showed high availability and demonstrated that distributed solar assets can contribute to downward frequency services, provided that they are remotely controllable and connected to a flexibility platform. This is particularly relevant for islands pursuing decarbonization, where solar should be valued not only for its energy but also for its contribution to system balancing. At the same time, the tests highlighted the difficulty of obtaining a reliable baseline for aggregated solar production, especially with a small and simulated asset pool. This underlines the need for improved forecasting methods at both day-ahead and very short term horizons, explicitly tailored to aggregated PV flexibility.

The large-scale VPP with a utility battery also demonstrated technical maturity, with high availability and the ability to deliver aFRR-like services. However, around one quarter of the tested activations showed some degree of underperformance. The analysis indicates that this is closely linked to the limited energy content of the battery and to state-of-energy management. For future applications, it will be important for market and product design to include appropriate reserve power rules and operating strategies that maintain sufficient energy margin in the battery. The simulations confirm that symmetric provision of upward and downward services, combined with a baseline that compensates for stand-by and cycling losses, can improve overall availability, especially in systems without liquid intraday markets.

For Use Case 2 (minimization of the consumption peak), the results validate the potential of smart charging and demand response to reduce peak load while preserving user comfort. A twelve hour smart charging session demonstrated a substantial cost reduction compared to uncoordinated charging, as well as the complete avoidance of residential peak periods. The Bovlabs platform showed that coordinated scheduling can align charging profiles with system objectives and price signals, while maintaining technical robustness along the full chain of EMS, simulators, pricing systems and charging infrastructure. In parallel, the small-scale VPP controlling aggregated air conditioning units confirmed the feasibility of load reduction via temperature set-point modulation, with good system availability. The analysis nevertheless points to challenges in estimating cooling baselines and in assessing the impact on end-user comfort, particularly when only a small number of simulated assets represent a larger population. These findings suggest that future work should include real-world pilots with direct feedback from users on thermal comfort, as well as standardized, cloud-based connectivity for air conditioning devices to enable cost-effective scaling.
From a flexibility management perspective, Use Case 2 also served to test the full workflow of the FMTP platform for medium and small assets, from baseline and flexibility offers to reservation,

dispatch and performance monitoring. The demonstration showed that the concept is technically feasible and that external flexibilities can be coordinated reliably. At the same time, it highlighted that manual configuration and daily offer processes would become a barrier at scale. The lessons learned point towards more automated, plug-and-play integration of assets, greater use of protocols such as MQTT for automatic registration, and the possible shift from daily offerings to longer term contracts, with only flexibility forecasts updated day by day.

For Use Case 3 (maximization of renewable energy sources), the demonstration met its main objective of aligning EV charging with local PV generation. The analysis shows that around seventy percent of charging energy in the tested scenarios occurred during daytime PV production hours, which reduced grid dependency during evening peaks and increased the utilization of local renewable output. While direct cost savings per session were modest compared to the peak shaving case, the results confirm that environmental objectives such as renewable maximization can be combined with acceptable economic performance and user convenience. The work with Trialog's LEC EMS (Troca) further showed that EV charging profiles can be adapted in simulation to meet both local building constraints and renewable optimization goals.

The lessons learned for this Use Case emphasize the interest of extending the approach to more chargers and to multi-objective optimization, where peak reduction and renewable maximization are treated jointly rather than in separate scenarios. They also highlight the need to confront the models with real infrastructure usage, as some results remain sensitive to assumptions on user behavior and building loads. On the technical side, the Bovlabs demonstration confirmed the reliability of multi-protocol communication over long durations and the ability of the EMS to integrate PV, price and charging data without failure. This underlines the transferability of renewable-optimized smart charging to other island systems with high renewable penetration and constrained grids.

For Use Case 4 (energy access), the work focused on the development and validation of a Local Energy Community HMI tool. The demonstration showed that it is possible to implement a robust technical solution that collects consumption and production data and displays them to end users on multiple devices, including computers and mobile phones. Even though the tests were carried out on simulated data, the tool proved effective in supporting demand response actions and in fostering a collective dynamic around energy awareness at community level. The analysis also makes clear that successful deployment in real environments requires adequate communication coverage and the ability to interface with smart meters and inverters. In this respect, the experience from Mayotte shows the importance of synchronizing such tools with the roll-out of smart metering infrastructure.
Beyond the Use Case specific findings, Deliverable D9.4 highlights several cross-cutting lessons. High quality performance analysis depends critically on data preparation, including consistent baselines, harmonized signal conventions and explicit documentation of assumptions. The simulations also show that flexibility solutions are not solely a technical issue. They interact with contractual arrangements for generation assets, regulatory frameworks for batteries and market products, the connectivity of end-user devices, and the scalability of integration processes for distributed assets.

Overall, D9.4 confirms that the MAESHA solutions are technically feasible, interoperable within a unified architecture and capable of delivering valuable services for frequency control, peak reduction, renewable maximization and community level engagement, at least under the conditions represented in the simulated environment. The deliverable identifies where the approaches are already mature enough to support deployment decisions and where additional field pilots would bring the greatest added value, in particular for comfort sensitive demand response, real world EV usage and battery based ancillary services. These insights provide a concrete basis for future implementation in Mayotte and for the replication and transferability work carried out under Work Package 10, so that the experience gained in MAESHA can inform the decarbonization strategies of other European islands.

1. Introduction

1.1. About MAESHA

MAESHA (Demonstration of Smart and Flexible Solutions for Decarbonising the Energy System of Mayotte) is a Horizon 2020 project. Its overarching objective is to support the decarbonisation of European islands by deploying innovative solutions for flexibility, storage and renewable integration, while ensuring that these solutions are adapted to local socio-economic and technical contexts. The project adopts a holistic approach, combining technical innovation with regulatory, economic and social analysis in order to create replicable pathways towards sustainable energy transitions in island territories.

Mayotte, as the main demonstration site, was chosen for its specific characteristics as an isolated non-interconnected island, heavily dependent on imported fossil fuels for electricity production. With a fast-growing population and rising electricity demand, Mayotte represents both the urgency and the opportunity of transitioning towards a more resilient, low-carbon energy system. The solutions designed within MAESHA were therefore intended not only to provide immediate insights for Mayotte, but also to serve as models for other islands facing similar challenges.

The project is structured into interlinked Work Packages. Early-stage activities focused on system analysis, modelling and stakeholder engagement (WP2 to WP5). WP6 and WP7 concentrated on the design and development of the technical solutions, including the Flexibility Management and Trading Platform (FMTP), Local Energy Community tools, demand response schemes, and energy management systems for electric vehicles and renewable integration. WP8 focused on the integration of these components, conducting interface testing and preparing demonstration scenarios. Finally, WP9 is dedicated to the demonstration phase itself, aiming to validate the solutions in operation and to assess their performance, before WP10 addresses replicability and transferability to other contexts.

1.2. Objectives of Work Package 9

Work Package 9 constitutes the demonstration phase of the MAESHA project. Its role is to validate the integrated operation of the solutions developed, to monitor their performance and to assess their contribution to the decarbonisation of Mayotte's energy system. Originally, WP9 was expected to follow directly from the integration work of WP8 and to provide real-world evidence of feasibility through the deployment of assets in Mayotte.

The main objectives of WP9 are to demonstrate the functioning of the MAESHA solutions under operational conditions, to verify interoperability and robustness of the components, to collect datasets for subsequent performance analysis, and to quantify technical, economic and social impacts through dedicated indicators. The knowledge gained is also intended to feed WP10, ensuring that replication and transferability to other island systems are properly supported.

As seen in D9.3, the physical deployment was halted and WP9 was reoriented towards a simulated demonstration. Nevertheless, the essence of its objectives remains intact: to demonstrate, assess and validate the MAESHA solutions within a coherent and credible framework.

1.3. Scope of this document

This deliverable presents the performance analysis of the MAESHA demonstration. It builds directly on Deliverable D9.3, which consolidated the datasets generated in the simulated environment, and applies the agreed KPI framework to quantify results for the four Use Cases. The purpose of this document is not to repeat the description of datasets or the rationale for simulation, as these have already been detailed in D9.3, but rather to transform those datasets into measurable outcomes and insights.

The scope covers the full chain from data preparation to KPI computation and interpretation. For each Use Case (frequency control, reduction of consumption peaks, maximisation of renewable energy use for EV charging, and energy access through Local Energy Communities) the deliverable recalls the functional objective, links it to a set of indicators, and presents the corresponding performance results. The focus is on the technical feasibility, accuracy, and stability of the services, as well as their potential contribution to the decarbonisation of Mayotte's energy system.

The analysis also includes a synthesis of cross-cutting insights. These highlight lessons learned from data curation, signal harmonisation and KPI calculation, and identify areas where further validation in real environments would be most beneficial. By doing so, the scope of D9.4 extends beyond a narrow technical evaluation: it provides recommendations for optimisation and establishes a clear link with WP10, where replication and transferability to other islands will be assessed.

2. Test plan and KPI Framework

Key Performance Indicators (KPIs) are measurable values that indicate how effectively the project achieves its objectives. KPIs are essential to evaluate the success of the simulated demonstrations and validate the technical feasibility of the MAESHA solutions. They quantify performance of technical solutions, ensure comparability between expected results and actual outcomes, guide decision-making for replication and prove impact to stakeholders.
In Maesha KPIs are classified in two categories:

- **Quantitative KPIs**: numerable indicators that measure the technical performance of the solution.
- **Qualitative KPIs**: address issues faced by the system operator and end users that can be solved.

2.1. Test Plan and KPIs for the Small-Scale Virtual Power Plant

The aim of this demonstration for Centrica's SS-VPP is to evaluate the feasibility and reliability of a small-scale Virtual Power Plant (SS-VPP) in providing grid services, utilizing simulated residential AC and PV systems. The test scenarios for the demonstration use cases were defined in Deliverable D8.5, which outlines the procedures, timelines, and expected outcomes. The trials were conducted in two phases: a preparation and trial phase, followed by a final demonstration. Each phase involved system integration, interface testing, and performance monitoring.

2.1.1. Test plan

The load-shifting potential of AC systems, under the constraints of end-user thermal comfort, was evaluated for their participation in Peak Load Reduction product. The goal of the trial was to demonstrate the ability of these assets to respond to load reduction signals from the system operator, thereby reducing system peak demand. The analysis includes the effectiveness in peak load reduction events.

The curtailment capabilities of PV inverters under simulated cloud shading conditions were examined on the downward automatic Frequency Reserve Restoration (aFRR) service. The trial aimed to validate the technical feasibility of this setup, focusing on system stability, real-time communication, and the effectiveness of PV curtailment in the cloudy conditions. The performance was measured against activation accuracy.

2.1.2. Key performance indicators

The evaluation of results is based on quantitative KPIs defined in Deliverable D4.1 (see Table 1). For the aFRR service provided by PV systems and Peak Load Reduction service provided by AC systems, the performance was evaluated based on how accurately the systems responded to FMTP dispatch events. The metric measured the difference between the power that was required and the power that was delivered during these events. A tolerance threshold was applied to determine whether the deviation was acceptable. The performance score was then calculated based on the worst-case deviation relative to the contracted capacity. This helped assess the system's ability to provide reliable and timely flexibility services.

Table 1 - Performance assessment metric for small-scale VPP

Attribute	Value
Error formula	$SuppliedMW(t) = Measure\ MW(t) – BaselineMW(t)$ $RequiredMW(t) = Setpoint\ MW(t) – BaselineMW(t)$ $MissedMW(t) = \lvert Required\ MW(t) – SuppliedMW(t) \rvert$ $DiscrepancyMW(t) = \min[\max[Missed\ MW(t) - tolerance\ MW(CCTU), 0], \text{Contracted Capacity}\ (CCTU)]$
Error tolerance	$tolerance\ MW(CCTU) = \pm 15\% \cdot \text{Contracted Capacity}\ (CCTU)$
Performance score	*Performance score (event) = 1 -Discrepancy MW(t) / Contracted Capacity MW (CCTU)*

2.2. Smart Electric Vehicle Charging Test Plan and KPIs

2.2.1. Minimization of Consumption Peak Use Case

2.2.1.1. Test Scope and Duration

The Minimization of Consumption Peak use case demonstration was conducted as a **single 12-hour charging session** spanning from evening (September 24, 18:30) until the following morning (September 25, 06:40). This test duration was selected to encompass both evening and morning peak demand periods, allowing comprehensive evaluation of the smart charging system's peak avoidance capabilities.

2.2.1.2. Test Scenario

The demonstration utilized a real-world charging scenario with the following parameters:

- **Vehicle Connection**: September 24, 18:30 with 66% State of Charge (SOC)
- **Target Requirements**: 100% SOC by departure time (September 25, 06:40)
- **Battery Capacity**: 205 kWh requiring 69.7 kWh energy delivery
- **Available Charging Window**: 12 hours 10 minutes
- **Maximum Charging Rate**: 22 kW

2.2.1.3. Baseline Comparison

Uncoordinated Charging Baseline: The predefined baseline scenario corresponds to immediate charging at maximum power (22 kW) upon vehicle connection at 18:30, representing typical uncoordinated charging behavior without smart optimization. A session with smart charging disabled is considered, which resulted in a total cost of **€22.53**.

2.2.1.4. Key Performance Indicators (KPIs)

The demonstration focused on two primary KPIs aligned with the use case objectives:

KPI 1: Reduction in Total Energy Cost (Behind-the-Meter Optimization)

- **Metric**: Percentage reduction in total charging cost compared to uncoordinated charging
- **Measurement Method**: Cost comparison between smart charging schedule and baseline immediate charging scenario
- **Data Sources**: Real-time energy pricing from EDM, actual charging power profiles

KPI 2: Peak Load Reduction via EV Smart Charging

- **Metric**: Avoidance of charging during residential peak demand periods
- **Measurement Method**: Analysis of charging schedule alignment with building consumption patterns and energy pricing peaks
- **Data Sources**: Building consumption data from simulators, charging session timestamps, energy price curves

2.2.1.5. Success Criteria

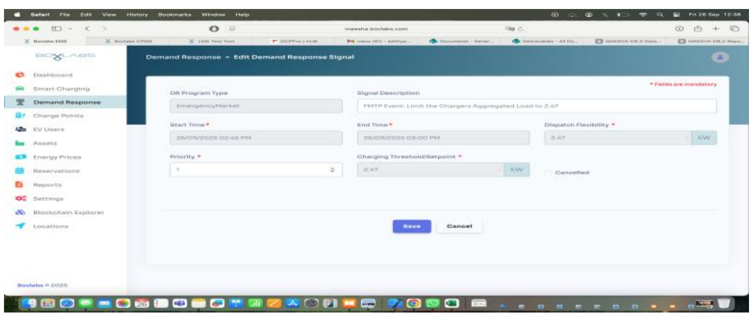
Success for this use case demonstration was defined as:

- Achieving user requirements (100% SOC by departure time) while implementing smart charging optimization
- Demonstrable cost reduction compared to uncoordinated charging
- Evidence of peak load avoidance through smart charging scheduling

2.2.2. Demand Response (DR) Event Use Case

2.2.2.1. Test Scope and Duration

The Demand Response event demonstration was conducted during an active charging session when a DR signal was received from CyberGrid's FMTP platform requesting consumption reduction for charging operations.



2	FMTP Event: Limit the Chargers Aggregate...	26/09/2025 02:45 PM	26/09/2025 03:00 PM	2.47	1	
3	FMTP Event: Limit the Chargers Aggregate...	26/09/2025 02:00 PM	26/09/2025 02:30 PM	1.97	1	
4	FMTP Event: Limit the Chargers Aggregate...	26/09/2025 01:11 PM	26/09/2025 01:20 PM	2	1	

Figure 1 - Signal received via FMTP seeking to reduce consumption. 3 signals received for various timestamps

2.2.2.2. Test Scenario

The demonstration utilized a real-time DR response scenario with the following parameters:

- **DR Signal Reception**: Load reduction request received via MQTT from FMTP
- **Signal Parameters**: Start time, end time, and target load reduction level
- **EMS Response**: Automatic schedule recomputation for affected vehicle
- **User Impact**: Maintained departure time requirements while reducing charging load

2.2.2.3. Baseline Comparison

No DR Response Baseline: Original charging schedule without DR signal compliance, representing standard operation without demand response participation.

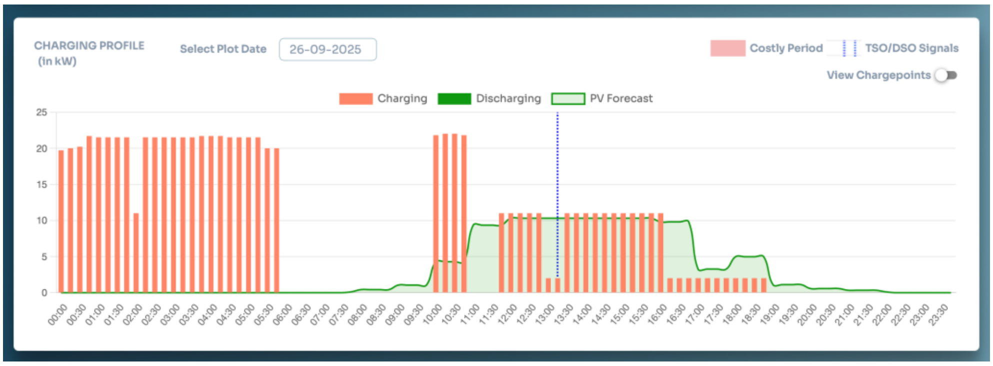


Figure 2 – The original schedule

2.2.2.4. Key Performance Indicators (KPIs)

The demonstration focused on DR compliance and system responsiveness:

KPI 1: Load Reduction Compliance

- **Metric**: Percentage compliance with requested load reduction during DR event period
- **Measurement Method**: Comparison of actual vs. requested load reduction
- **Data Sources**: DR signal requirements, actual charging power during event

2.2.2.5. Success Criteria

Success was defined as:

- Successful DR signal reception and processing via MQTT
- Automatic schedule re-computation maintaining user requirements
- Demonstrable load reduction compliance during DR event period

2.2.3. Maximization of Renewable Energy Sources for EV Charging Use Case

2.2.3.1. Test Scope and Duration

The Maximization of Renewable Energy Sources use case demonstration was conducted as a single-day charging session on September 25, 2025, from 07:49 AM (arrival) to 01:48 PM (departure). This test duration was specifically selected to coincide with daytime photovoltaic generation periods, allowing comprehensive evaluation of the smart charging system's renewable energy utilization capabilities.

2.2.3.2. Test Scenario

The demonstration utilized a Tesla vehicle with the following parameters:

- **Vehicle Connection**: September 25, 2025, 07:49 AM with 30% State of Charge (SOC)
- **Target Requirements**: 100% SOC by departure time (September 25, 01:48 PM)
- **Battery Capacity**: 75 kWh requiring 52.5 kWh energy delivery (70% SOC increase)
- **Available Charging Window**: 5 hours 59 minutes
- **PV Generation Window**: Approximately 08:00 - 17:00 based on forecast curve

2.2.3.3. Baseline Comparison

Uncoordinated Charging Baseline: The predefined baseline scenario corresponds to immediate charging at maximum available power upon vehicle connection at 07:49 AM, without consideration of PV generation timing or renewable energy optimization. This baseline session cost **€10.02**.

2.2.3.4. Key Performance Indicators (KPIs)

The demonstration focused on renewable energy utilization optimization with the following KPIs:

KPI 1: Renewable Energy Self-Consumption Maximization

- **Metric**: Alignment of charging schedule with PV generation periods
- **Measurement Method**: Analysis of charging timing with PV generation
- **Data Sources**: PV generation forecast, charging session timestamps, actual charging power profiles

KPI 2: Grid Dependency Reduction

- **Metric**: Percentage of charging energy sourced from renewable generation vs. grid supply
- **Measurement Method**: Comparison of charging periods with PV generation availability

Data Sources: PV generation curves, charging schedule optimization results

2.2.3.5. Success Criteria

Success for this use case demonstration was defined as:

- Achieving user requirements (100% SOC by 01:48 PM departure) while maximizing renewable energy utilization

- Demonstrable alignment of charging schedule with PV generation periods
- Cost optimization through renewable energy integration
- Reduced grid dependency during low renewable periods

2.3. Test plan and KPIs for the Flexibility Management and Trading Platform

2.3.1. KPIs related to the FMTP

The Flexibility Management and Trading Platform (FMTP) has the function of a communication hub, flexibility aggregation and management and handling of flexibility offers from connected assets and intermediary platforms. The demonstration architecture is described in D9.3.
As the FMTP does not provide its own flexibility and given the fact, that the flexibility offers were mainly provided from simulated assets, the FMTP did not provide its own use case but was providing the enabling framework to demonstrate the use case UC1 to UC3. Therefore, the analysis of the FMTP demonstration focused on qualitative KPIs rather than quantitative KPIs.

The most relevant quantitative KPIs focused on the following topics:

- System availability: Describes the percentage of time that the FMTP and linked modules was working correctly and available for the user. The inverse unavailability is measured in minutes/week.
- Communication availability: Describes the percentage of time that the communication between FMTP and subsystems was working correctly. The inverse unavailability is measured in minutes/week.
- Available power and flexibility
- Average flexibility to power ratio
- Activation performance

More important, the qualitative objectives of the demonstration were

- Investigation of the practicability and feasibility of the flexibility offering and reservation process
- Proof of mid-term stability of the FMTP and its interfaces. This objective can be described by the aforementioned KPIs “System availability” and “Communication availability”.
- Test of methods to maintain the SOC level of a battery that provides ancillary services to the system operator in range that ensures – in each moment – power and energy availability for at least 4h in the future. The learnings of the analysis can be described by the KPI “Power availability of BESS after implementation of SOC-Management algorithm”
- Experience with management of real assets. This objective got out-of-scope after the project officer had stopped the real deployment of solutions on Mayotte. In fact only two real assets were involved in the tests:
    - an electric vehicle charged at the EDM headquarter on Mayotte and monitored via the smart EV charging platform of Bovlabs
    - A combination of PV and battery installed in CyberGrid’s test lab in Maria Enzersdorf, Lower Austria was used for a long-term test of the developed C&I RTU.

2.3.2. Test plans involving the FMTP

Depending on the availability of the different asset simulators and sub-systems, the following demonstration activities were carried out sequentially:

- Demonstration with Centrica's small-scale VPP from 2025-02-27 to 2025-05-27. The tests included UC1 and UC2 with additional participation of the large-Scale (C&I) VPP and the battery simulator. Setpoint were generated automatically.
- Tests with TRIALOG's EMS (Troca) from 2025-06-02 to 2025-07-13 and from 2025-08-18 to 2025-09-19 (with interruptions) for the purpose of demonstrating UC2 and UC3. Activation setpoints were triggered manually.
- Tests with Bovlabs' smart EV charging platform from 2025-09-11 to 2025-10-05. The test provided data for UC2 and UC3. Activation setpoints were triggered manually.
- Test for simulating the behavior of a battery in symmetric aFRR service (UC1) from 2025-03-17 to 2025-09-30 (with interruptions). The C&I VPP participated as a second asset all the time. The aFRR setpoints were generated automatically.
- Long-term stability tests with the commercial and residential C&R RTU prototype in order to analyze the behavior of software and hardware from 2025-03-18 to 2025-07-18.

2.4. LEC EMS APPLIED TO EV CHARGING TEST PLAN AND KPI

This part will focus on the definition of the test plan and KPIs associated with the demonstration run for the LEC EMS applied to EV charging.

The following three different use case configurations were tested:

1. Minimization of the consumption peak, local adaptation: peak shaving objective using EV charger consumption adaptation based on local building consumption data
2. Minimization of the consumption peak, adaptation with external signals: peak shaving objective using EV charger consumption adaptation based on power set points received from a flexibility aggregator
3. Maximization of renewable energy sources: power consumption adaptation for EV charger based on local power generation data from PV

2.4.1. UC 2 Minimization of the consumption peak: local adaptation

2.4.1.1. Data usage

Required Inputs

Input type	Source	Description
Instantaneous building power consumption	FMTP (Cybergrid)	simulated data Trialog associates this data to a building that would be linked to a grid point including the EV charger cluster (targeted size of the cluster=1 station, 22kW)
EV charger characteristics and	Bovlabs's management system	details of the received data

session global information		list of stations with their global characteristics (max power), current charging sessions start date time, end date time Trialog picks 1 station to be used for the demonstration of this configuration the station with the most regular session occurrences, to be decided together with Bovlabs Trialog simulates the power consumed from charger based on charger characteristics and profile computation from Troca EMS
Static configuration of LEC EMS	Internal (EMS)	global power limitation per cluster (for a cluster of 1 station, global limit<max power for the station) global power limitation per building energy required per charging sessions energy to be delivered to reach battery end of charge time bounds for instantaneous power (building) duration for which a read value is to be considered as applicable. Example: building consumption reading of 5kW at 10h50 the EMS considered it will be the building power level until 10h55 beyond, no building power is considered this is updated with every new reading

Data transformation

The LEC EMS (Troca) computes charging profiles based on charger characteristics, available building power and charging session status.

Example:

- grid point limitation=230kW
- cluster limitation=10kW
- station max power=22kW
- without building info=> max power level during the charge = 10kW
- with a building consumption of 180kW => local max power level of 10kW
- with a building consumption of 235kW => local max power level of 5kW

Expected outputs

Output type	Target	Description
Charging sessions profiles	Internal (EMS)	Profiles as computed by the EMS

2.4.1.2. Test description

Phase	Name	Associated testing tasks
1	Validate service connection and inputs	technical connection data scaling Based on building consumption tendencies, the EMS is configured so that significant adaptations occur during the demonstration phase station selection agreement with Bovlabs of the selected station Trialog only needs a station with regular charging sessions (at least one per day)
2	External input validation	validate building data reception frequency received values validate charger data reception received values charging session occurrences
3	Profile computation validation	Validate profile output with inputs and configuration

2.4.1.3. KPI

Type	Description
Qualitative	Apply EV charger power limitation based on available building power
Quantitative	Percentage of energy charged per session compared to base line
Quantitative	Comparison of average energy charged per session depending on base line

2.4.2. UC 2 Minimization of the consumption peak: adaptation with external signals

2.4.2.1. Data usage

Required Inputs

Input type	Source	Description

Power set points	FMTP (Cybergrid)	Trialog associated the set points to a cluster of EV chargers (targeted size of the cluster=1 station, 22kW)
EV charger characteristics and session global information	Bovlabs's management system	details of the received data list of stations with their global characteristics (max power), current charging sessions start date time, end date time Trialog picks 1 station to be used for the demonstration of this configuration the station with the most regular session occurrences, to be decided together with Bovlabs Trialog simulates the power consumed from charger based on charger characteristics and profile computation from the EMS
Static configuration of LEC EMS	Internal (EMS)	global power limitation per cluster (for a cluster of 1 station, global limit<max power for the station) energy required per charging sessions energy to be delivered to reach battery end of charge

Data transformation

The LEC EMS (Troca) computes charging profiles based on charger characteristics, aggregator set points and charging session status. The set points received from the aggregator are to be followed for the charging profiles.

Expected outputs

Output type	Target	Description
Charging sessions profiles	Internal (EMS)	Profiles as computed by the EMS
Real time data sent to the flexibility aggregator	FMTP (Cybergrid)	Associated with the device consumption: active power (metering data) min/max flexibility margins
Flexibility schedule forecast	FMTP (Cybergrid)	Forecast to be sent for every day external signals should be expected.

2.4.2.2. Test description

Phase	Name	Associated testing tasks

1	Validate service connection and inputs	technical connection Station selection agreement with Bovlabs of the selected station Trialog only needs a station with regular charging sessions (at least one per day)
2	External input validation	validate charger data reception received values charging session occurrences validate set points received from Cybergrid timing values relevance
3	External output validation	validate flexibility forecast sending frequency values validate real time flex/current data sending values frequency
4	Profile computation validation	Validate profile output with inputs and configuration

2.4.2.3. KPI

Type	Description
Qualitative	Apply EV charger power limitation based on flexibility signals
Quantitative	Percentage of sessions affected by external signals
Quantitative	Percentage of session with successful external set points compliancy

The compliancy with the set points received from the flexibility aggregator is defined by:

- the power level in the charging schedule correspond to the target power level in the set point (+/- power margin)
- the duration of the adaptation corresponds to the one defined in the set point (+/- time margin).

2.4.3. UC 3 Maximization of renewable energy sources

2.4.3.1. Data usage

Required Inputs

Input type	Source	Description
Instantaneous power generation from PV	FMTP (Cybergrid)	simulated data Trialog associated this data to a PV source attached to a single EV charger cluster (targeted size of the cluster=1 station, 22kW)
EV charger characteristics and session global information	Bovlabs's management system	details of the received data list of stations with their global characteristics (max power), current charging sessions start date time, end date time Trialog picks 1 station to be used for the demonstration of this configuration the station with the most regular session occurrences, to be decided together with Bovlabs Trialog simulates the power consumed from charger based on charger characteristics and profile computation from the EMS
Static configuration of LEC EMS	Internal (EMS)	global power limitation per cluster (for a cluster of 1 station, global limit<max power for the station) energy required per charging sessions energy to be delivered to reach battery end of charge time bounds for instantaneous power (PV) duration for which a read value is to be considered as applicable. Example: PV power generation reading of 5kW at 10h50 the EMS considered it will be the PV power level until 10h55 beyond, no PV power is considered this is updated with every new reading

Data transformation

The LEC EMS (Troca) computes charging profiles based on charger characteristics, available PV power and charging session status. The PV generated power is used as an additional available power that can be used to exceed cluster limitation.

Example:

- cluster limitation=10kW
- station max power=22kW
- without PV generation => max power level during the charge = 10kW
- with a PV generated power of 5kW => local max power level of 15kW

Expected outputs

Output type	Target	Description
Charging sessions profiles	Internal (EMS)	Profiles as computed by the EMS

2.4.3.2. Test description

Phase	Name	Associated testing tasks
1	Validate service connection and inputs	technical connection data scaling Max PV power generation is to be selected so that it significant adaptations can occur during the demonstration station selection agreement with Bovlabs of the selected station Trialog only needs a station with regular charging sessions (at least one per day)
2	External input validation	validate PV data reception frequency received values validate charger data reception received values charging session occurrences
3	Profile computation validation	Validate profile output with inputs and configuration

2.4.3.3. KPIs

Type	Description
Qualitative	Apply EV charger power limitation based on available power generated from PV
Quantitative	Percentage of charged energy per session compared to base line
Quantitative	Comparison of average energy charged per session depending on base line
Quantitative	Percentage of charged energy per session related to PV generation

3. Performance Analysis (vs KPIs)

3.1. Overview of results per use case

3.1.1. Use case 1

Table 2 - Results of Use Case 1

Expected results	DEMO results
Quantitative objectives: • Specific demo KPIs for the Use Case 1. SS VPP: deviation between the delivered and requested activations < 10% 2. Power availability of BESS after implementation of SOC-Management algorithm >99% 3. All involved systems/components: downtime in h/week 4. Power availability of SS-VPP and BESS 5. Usable capacity of BESS considering SOC management 6. Amount of underperformed activation **Qualitative objectives:** • Describe in a few lines the benefit of using the component in the Use Case demo for stakeholders: 1. Mayotte's inhabitants: Indicate potentials for costs saving strategies 2. Mayotte's electrical grid managers (EDM): The demonstration proves to the System Operator that external systems like FMTP and Small Scale-VPP are technically ready to provide grid frequency ancillary services and have the potential to lower costs for the system operation and increase grid stability for all users. Aggregation and communication systems are available on the market and are an alternative to investment in further generation assets and BESS assets by the system operator.	KPIs have low relevance because all assts were simulated. 1. SS VPP: deviation between the delivered and requested activations < 10% a) Below the target performance was observed in less than 2% of activations (after applying the fix) 2. Power availability of BESS after implementation of SOC-Management algorithm >99% a) achieved: > 95% 3. All involved systems/components: downtime in h/week a) < 73 min/week 4. Power availability of SS-VPP and BESS a) Flexibility-to-Power ratio of 19.4% for SS-VPP b) Flexibility-to-Power ratio of >90% for BESS 5. Usable capacity of BESS considering SOC management a) Simulated random activation signal: 30% of BESS power must be reserved for SOC management. b) Potential long-term system Support (not tested): 50% of BESS power must be reserved for SOC management 6. Amount of underperformed activation of SS VPP with PV: a) 2% of activations showed underperformance (15 min evaluation interval) (Deviation of -10% or worse) b) Number of activations: 1958 of which with setpoint <-20 kWh: 1690 c) Average overperformance for activations requests of <-20kWh: +36% (+48% after fix of VPP) 7. Amount of underperformed activation of LS VPP: a) 24% of activations showed underperformance (15 min evaluation interval) (Deviation of -10% or worse) which was based by

	the ramp-up behaviour of the simulated assets. b) Number of activations: 836 of which with setpoint >500 kWh: 836 c) Average underperformance for activations requests of >500kWh: -19.5% Conclusions: VPPs can provide aFRR ancillary services for the SO: • The SSVPP for PV offered negative flexibility of approx. 19% of the generated power and showed slight underperformance during fast-changing weather conditions, impacting the overall success rate. The communication and availability of the SS-VPP were very stable throughout the testing phase. • In case of a LSVPP (C&I) the backup power should be at least 30% to provide a reliable aFRR service.

3.1.2. Use Case 2

Table 3 - Results of Use Case 2

Expected results	DEMO results
Quantitative objectives: Specific demo KPIs for this Use Case 1. All involved systems/components: downtime in h/week 2. Small Scale VPP: success rate for the peak load reduction activations > 80% 3. FMTP: • Power availability and energy availability of SS-VPP and EMS systems • Usable capacity of BESS considering SOC management • Amount of underperformed curtailments **Qualitative objectives:** Benefit of using the components in the Use Case demo for stakeholders: 1. Mayotte's inhabitants • Indicate potentials for costs saving strategies 2. Mayotte's electrical grid managers (EDM) This use case aims at minimizing the consumption peak by implementing a flexibility market for load	For the demonstration with the LEC EMS, the following results were obtained: **Mode 1**: local peak reduction based on building consumption related to grid connection point for EV charger (simulated) • compared to the default behaviour, there is an average of 60% less energy charged per session • it represents a reduction of an average of 52 kWh per charging session • => the adaptation was successful, but only with a low threshold to provided results for most of the charging sessions. A higher threshold might be considered if the objective is only to prevent from tripping the switch **Mode 2**: peak reduction using external signals • 37% of the sessions are concerned by external signals • 27% of these sessions showed a successful adaptation compliant with the external signals • default behaviour followed 97% of the time during sessions

shedding and/or load shifting to enable new flexibility assets to support the system operator in operating the grid. This use case has a significant potential to reduce generation costs and increase system stability at peak hours and is thus highly relevant for the system operator EDM. 3. Mayotte's EV users The use case demonstration can provide an outlook for EV owners about expected EV charging behaviour during critical hours and potential cost savings related to eV charging	• => adaptation was proved to possibly be successful, but some errors related to the signals values and system behaviour led to inaccurate adaptations. *Note: results obtained for the 27 charging sessions that occurred during the demonstrations. For mode 1, the threshold for limiting the charger consumption was set to 11% of the max consumption of the building (due to an average low consumption from the building considering its maximum).* **Bovlabs** • Connected vehicle at 18:30 with 66% SOC, achieved 100% SOC by 06:40 departure time while maintaining user convenience and preferences. • The charging schedule avoided residential peak demand periods (18:00-22:00) and morning peaks, preventing grid stress conditions. • Shifted 69.7 kWh charging load from expensive peak periods (€0.285/kWh) to low-cost periods (€0.079/kWh). • 54.3% cost savings (€9.305 for this session, €12.45 on average) compared to immediate charging. • 45 kg CO_2 emissions reduction (20 kg on average). • All interfaces (MQTT, REST APIs) maintained stable connections throughout the 12+ hour charging session with no communication failures. **SS-VPP** The performance score for AC control is below the expected success rate of 80% that was targeted during the test plan. Low scores which can be attributed to the challenges of estimating the baseline operation and available flexibility in the conditions of unpredictable user behaviour. Another factor contributing to the low scores is a small population of simulated ACs (only 5 assets were used and scaled to a larger pool capacity). The communication and availability of the SS-VPP were stable throughout the testing phase.

3.1.3. Use Case 3

Table 4 - Results of Use Case 3

Expected results	DEMO results
Quantitative objectives: Specific demo KPIs for this Use Case 1. Calculated cost saving for the Demo week compared to dependence on grid for charging. 2. Maximise usage from PV production for smart charging 3. Minimise environmental impact from charging EVs. 4. Charging needs of simulated vehicles are satisfied. Qualitative objectives: Benefit of using the component in the MAESHA demo for stakeholders: 1. Mayotte's inhabitants: This use case can demonstrate potential costs and CO2 saving strategies based on EMS, that will help building managers and residential users to reduce electricity costs 2. Mayotte's EV users The use case demonstration can provide an outlook for EV owners about potential costs savings by advanced EV charging behaviour managed by an EMS.	For the demonstration with the LEC EMS, the following results were obtained: **Maximisation of PV production usage for smart charging (simulated)** • the share of energy charged per session related to PV generation represents on average 25% of the total **Charging needs satisfied for simulated EV**: • compared to the default behaviour, there is an average of 14% less energy charged per session • the average charged energy per session is equal to ~72kWh • this is superior to the usual battery capacity (70kW) • => needs satisfied. The default power when there is no PV generation could have been chosen to be lower *Note: results obtained for the 27 charging sessions that occurred during the demonstrations and with a consumption set to 68% of the max power when no PV power is available.*

3.1.4. Use Case 4

Table 5 - Results of Use Case 4

Expected results	DEMO results
Quantitative objectives: • Specific demo KPIs for this Use Case 1. FMTP dataflow reception delay < 10 minutes 2. Continuity of service of the HMI without loss of data from FMTP platform >1 week) 3. Continuity of access to HMI without any connection issue > 1 week. **Qualitative objectives:** • Describe in a few lines the benefit of using the component in the MAESHA demo for stakeholders: • Mayotte's inhabitants: The LEC HMI Tool is a Proof of Concept that a collective of participants can have a tool to track daily production and consumption of a group of	• Quantitative objectives: ○ Specific demo KPIs for this Use Case 1. OK, delay of reception < 10 minutes 2. No data loss when FMTP server is operation normally 3. Out of the interruption issues on FMTP server, the LEC HMI continuously display the data received. • Qualitative objectives: 1. OK, described in WP9 deliverables reports.

participants to maximize the use of PV production (for both energy and economic reasons) and to set-up Demand/Response active behaviour.	

3.2. Small-scale VPP Performance Analysis

This section presents the analytical outcomes derived from the datasets introduced in D9.3, focusing on both market behaviour and system performance. The analysis is structured in two parts: the first examines statistical patterns in market data submissions and activations, while the second evaluates the technical performance of the flexibility services based on predefined KPIs. Together, these insights provide a comprehensive understanding of how the MAESHA system operated under real-world conditions and how effectively it delivered on its flexibility objectives.

3.2.1. Market data statistics

The market summary measurements dataset offers a detailed view of how assets participated in the flexibility markets over the 88-day trial period. Table 6 compares the activity of air conditioning (AC) and photovoltaic (PV) systems across several key metrics. Both asset types submitted data consistently, with AC assets recording 87 submission dates and PV assets 84. The total number of records was nearly identical, with 8,368 for AC and 8,380 for PV.

However, the nature and scale of their activations differed significantly. AC systems contributed a total volume of upward activations of 27,765 MWh. In contrast, PV systems showed a downward activation volume of -31,313 MWh. The paid activation volumes further highlight this contrast: AC assets received compensation for 12,850 MWh of activations, while PV assets recorded a negative paid activation volume of -19,260 MWh.

Table 6 - Statistics of market summary measurements

Metric	AC	PV
Time Range	2025-02-27 to 2025-05-27 (88 days)	2025-02-27 to 2025-05-27 (88 days)
Number of Submission Dates	87	84
Total Number of Records	8,368	8,380
Total volume of Activation (+)	27,765 MWh	176 MWh
Total volume of Activation (–)	- 4,518 MWh	- 31,313 MWh
Total volume of Paid Activation	12,850 MWh	- 19,260 MWh

3.2.2. Performance assessment

The performance of the flexibility services was evaluated using the performance score metric, which reflects how accurately and consistently assets responded to market signals and control setpoints. The analysis focused on two asset types—air conditioning (AC) systems and photovoltaic (PV) systems—each playing distinct roles in the flexibility framework.

The performance of air conditioning (AC) systems in delivering Peak Load Reduction (similar to manual Frequency Restoration Reserve (mFRR)) service was evaluated using both time-series and statistical analyses. As shown in Figure 3, the AC systems had varying success in tracking the peak load reduction setpoints over the observed period (May 1–4, 2025), with active power adjustments not always responding accurately to the control signals. The corresponding performance scores, plotted on the secondary axis, varied from low to high, indicating unreliable responsiveness to system operator commands. This is further supported by the histogram in Figure 4, which illustrates that two-fold distribution of performance scores concentrated near 0.2 and 1.0. Most of the low scores are observed during the activation periods. The low scores can be attributed to the challenges of estimating the baseline operation and available flexibility in the conditions of unpredictable user behaviour. Another factor contributing to the low scores is a small population of simulated ACs (only 5 assets were used). The performance score is therefore below the expected success rate of 80% that was targeted during the test plan.

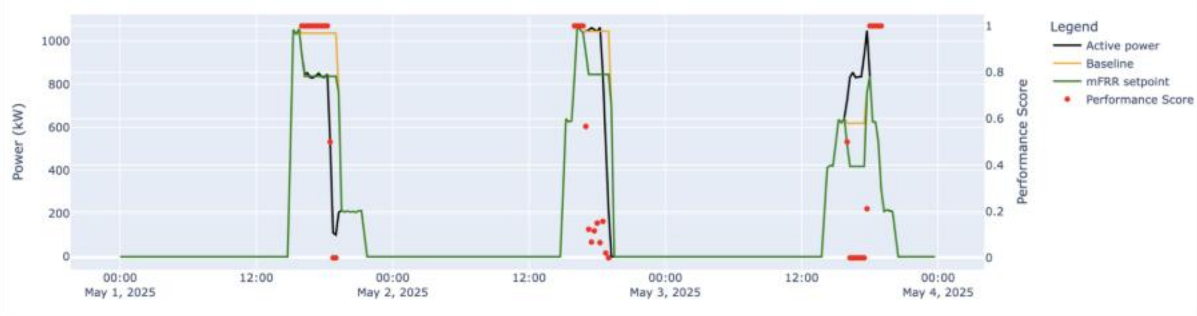


Figure 3 - The operation of the mFRR services and performance of AC

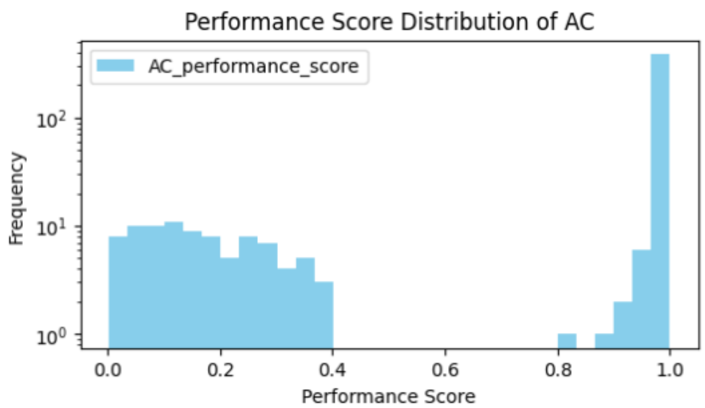


Figure 4 - Distribution of AC performance score

The performance of photovoltaic (PV) systems in delivering automatic Frequency Restoration Reserve (aFRR) services was evaluated through time-series tracking and statistical distribution of performance scores. As illustrated in Figure 5, the PV systems generally followed the aFRR setpoints with reasonable accuracy, though some deviations are visible, particularly during periods of rapid irradiance changes. These fluctuations are primarily due to the inherent variability of solar generation, which is sensitive to cloud cover and weather dynamics. Despite these challenges, the performance scores—represented by red dots—remained relatively high throughout the observed period (March 31–April 2, 2025). This is corroborated by Figure 6, which shows a histogram of performance scores spread over the whole performance range, indicating that the PV systems were largely unstable in meeting control targets. However, when reflecting on the predefined success criterion of achieving a deviation between the requested power and actual power below 10% for aFRR activations, the PV systems' performance may have been constrained by their limited controllability and the stochastic nature of solar irradiance. These factors likely contributed to underperformance during fast-changing weather conditions, impacting the overall success rate.

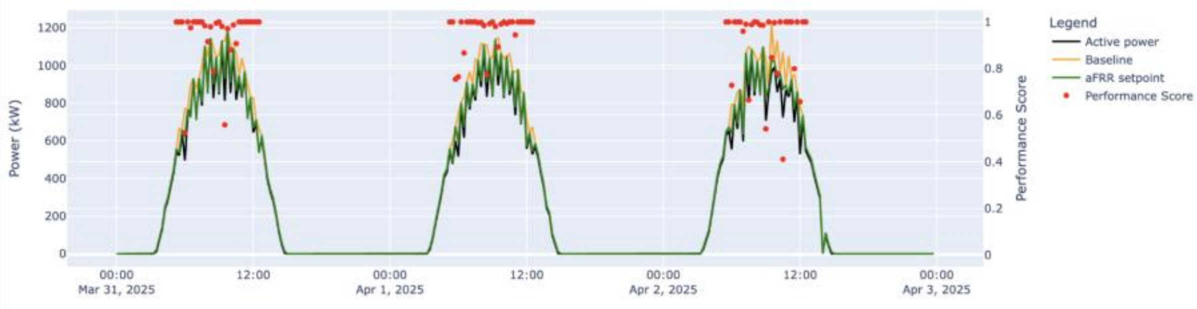


Figure 5 - The operation of the aFRR services and performance of PV

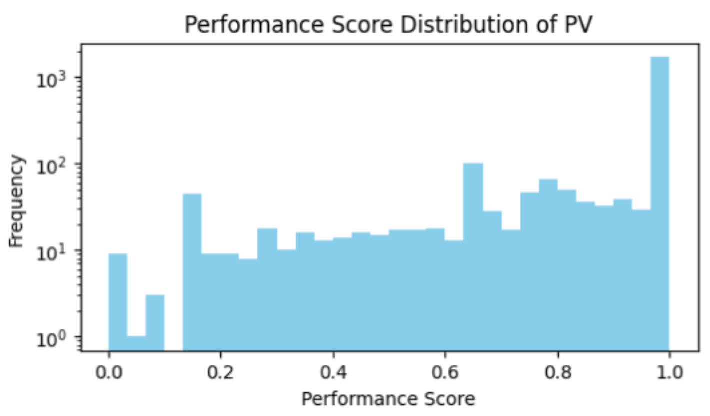


Figure 6 - Distribution of PV performance score

Together, the analysis results highlight the challenges of providing flexibility services with residential assets. The main reasons contributing to the low activation performance of the SS-VPP are caused by the stochasticity of the individual assets, like user behaviour and site environmental conditions. As mentioned above, only few simulated assets were used in the demo to represent large pool, and it is expected that the performance improves for a larger population of assets.

3.3. Analysis of smart electric vehicle charging

3.3.1. Minimization of consumption peak use case

The EMS computes the charging session and the schedule for the current session is given in the below figure.

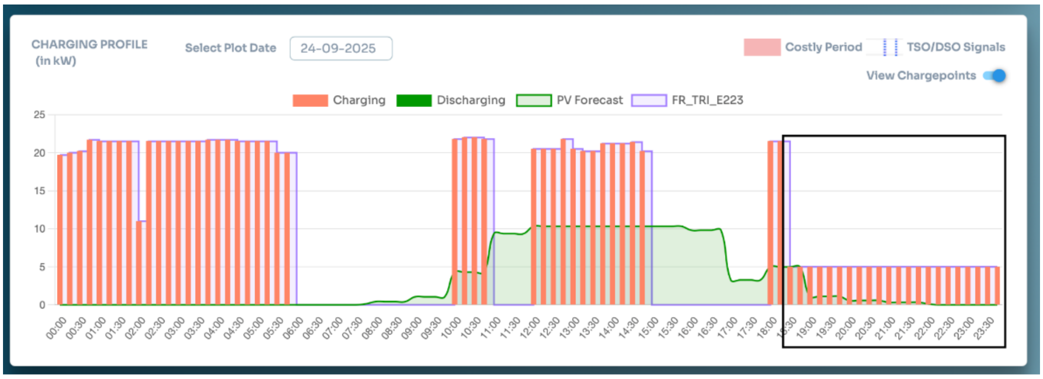


Figure 7 - Schedule for the 24th of September evening (black block to the right). The minimum charging rate that the charge point can deliver (5kW) is set during this period

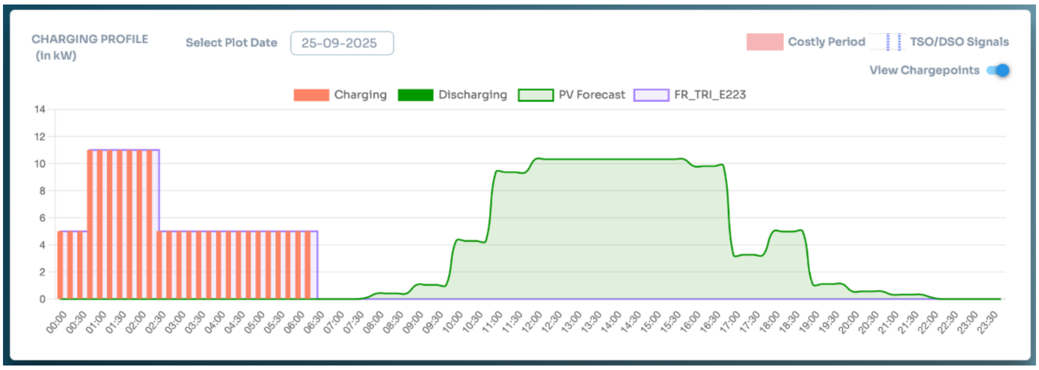


Figure 8 - Schedule for the 25th of September morning (Charging rate increases during off-peak hours up to 11kW over 4 timeslots).

The EV user is communicated regarding the charging session. The below figure shows the charging schedule communicated to the mobile application via the EMS.

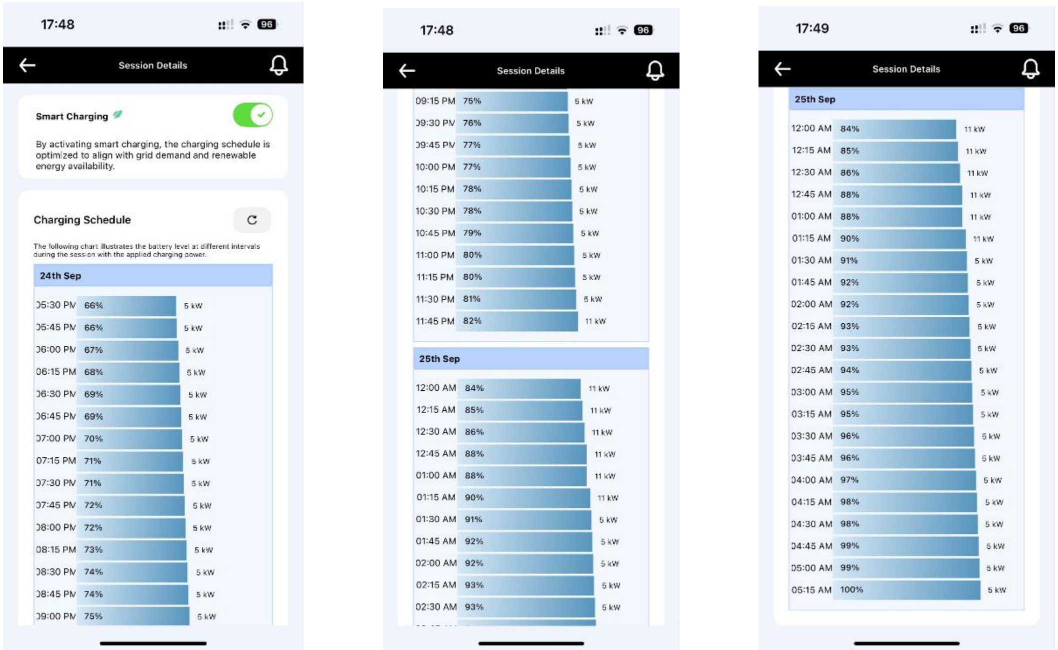


Figure 9 - Charging schedule as seen by the EV user in the mobile application

3.3.1.1. KPI 1 Performance: Energy Cost Reduction

Achieved Results

- **Smart Charging Cost**: €14.30
- **Uncoordinated Charging Cost**: €22.53 (smart charging disabled session)
- **Absolute Savings**: €8.23 per charging session
- **Percentage Cost Reduction**: **36.53%**
- **Demonstrated Cost Efficiency**: Smart charging system delivered significant cost optimization through intelligent scheduling

Performance Analysis

The smart charging system achieved significant behind-the-meter cost optimization by:

- **Time-of-Use Optimization**: 53.2% of charging occurred during the cheapest rate period (€0.079/kWh)
- **Peak Price Avoidance**: Successfully avoided expensive €0.285/kWh periods that would have been used in uncoordinated charging
- **Rate Reduction**: Achieved €0.118/kWh average rate reduction compared to baseline

3.3.1.2. KPI 2 Performance: Peak Load Reduction

Achieved Results

Evening Peak Management (September 24):

- **Residential Peak Period**: 18:00-22:00 (demand 3-3.5 kW)
- **Smart Charging Response**: Reduced to minimum charging rate of 5 kW during peak periods
- **Peak Load Minimization**: Used minimum allowable charging rate rather than maximum 22 kW during residential peaks

Morning Peak Management (September 25):

- **Off-Peak Optimization**: Increased charging to maximum of 11 kW during early morning off-peak periods
- **Load Distribution**: Concentrated higher charging rates during low-demand, low-cost periods

Performance Analysis

The peak load reduction was achieved through:

- **Peak Rate Minimization**: Reduced charging to minimum 5 kW rate during residential peak periods instead of avoiding charging completely
- **Off-Peak Maximization**: Increased charging to 11 kW during optimal early morning periods (Sept 25)
- **Load Shifting Success**: Moved intensive charging from expensive peak periods to low-cost, low-demand periods
- **Grid-Friendly Timing**: Concentrated higher charging rates when residential baseline was minimal

- **Intelligent Rate Management**: Utilized minimum charging during peaks and maximum allowable rates during off-peak periods

3.3.1.3. *System Performance Metrics*

Communication and Integration

- **Interface Stability**: All MQTT and REST API communications maintained stable connections throughout the 12-hour session
- **Data Collection**: Achieved zero data gaps across all monitored systems
- **Response Time**: EMS successfully processed real-time data and generated optimized charging schedules within 15-minute intervals

User Experience

- **Requirement Fulfillment**: Successfully achieved 100% SOC target by 06:40 departure time
- **Convenience Maintenance**: No user intervention required during the charging session

Flexibility: Demonstrated system capability to handle varying user requirements and constraints

3.3.2. DR event Use Case

The EMS successfully received the DR signal from CyberGrid's FMTP platform and automatically recomputed the charging schedule to comply with the requested load reduction. The system reduced charging power during the specified DR event period while maintaining the vehicle's departure time requirements, demonstrating effective demand response participation and grid flexibility support.

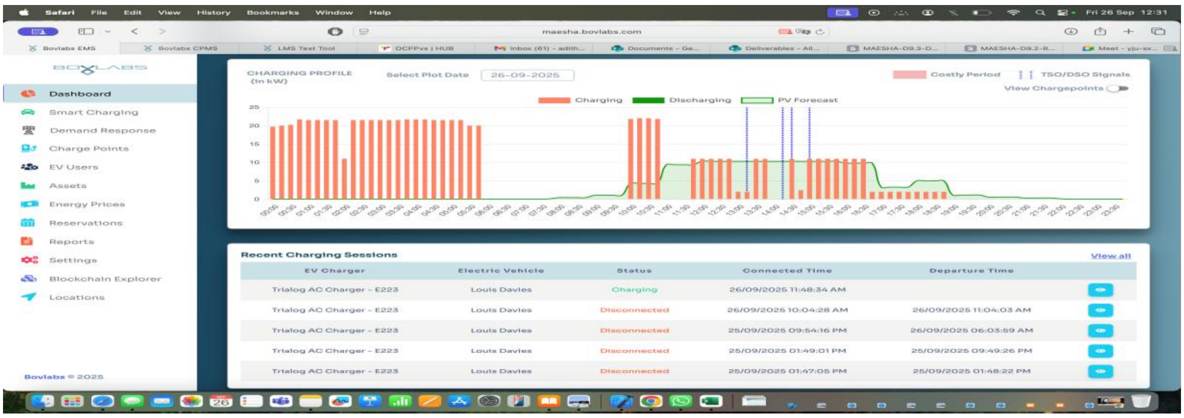


Figure 10 - The recomputed schedule based on the DR signal. The blue dashed vertical line represents the Grid event from the received from the FMTP

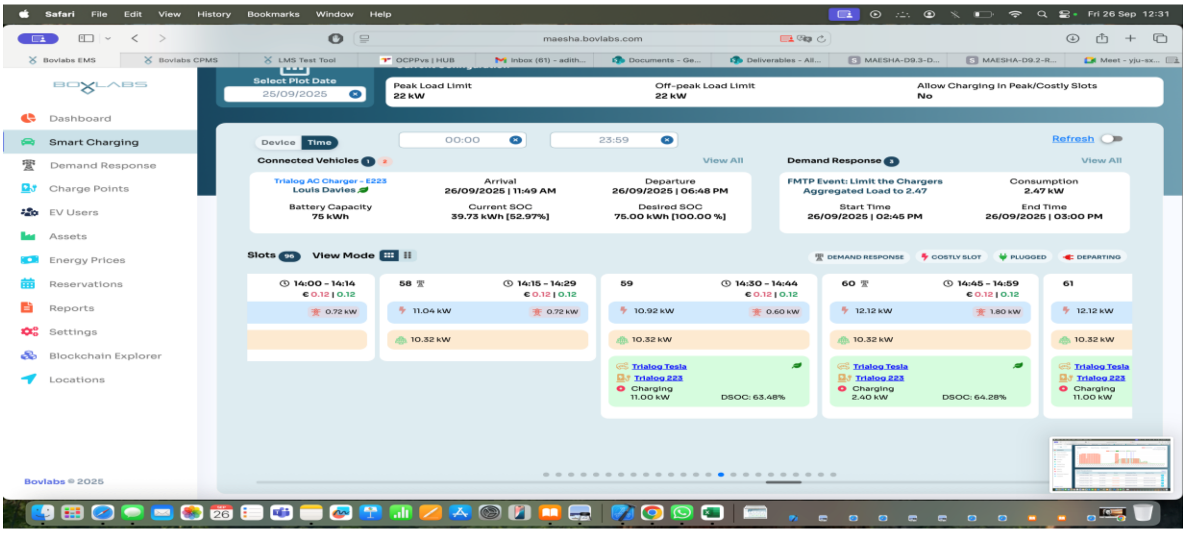


Figure 11 - The EMS responding to these signals. The smart charging schedules for the DR timeslot

3.3.3. Maximization of Renewable Energy Sources for EV Charging Use Case

PV generation forecasting enabled proactive optimization of charging schedules, while real-time adaptation ensured charging rates were continuously adjusted to match actual renewable generation. This combination enhanced both efficiency and grid alignment.

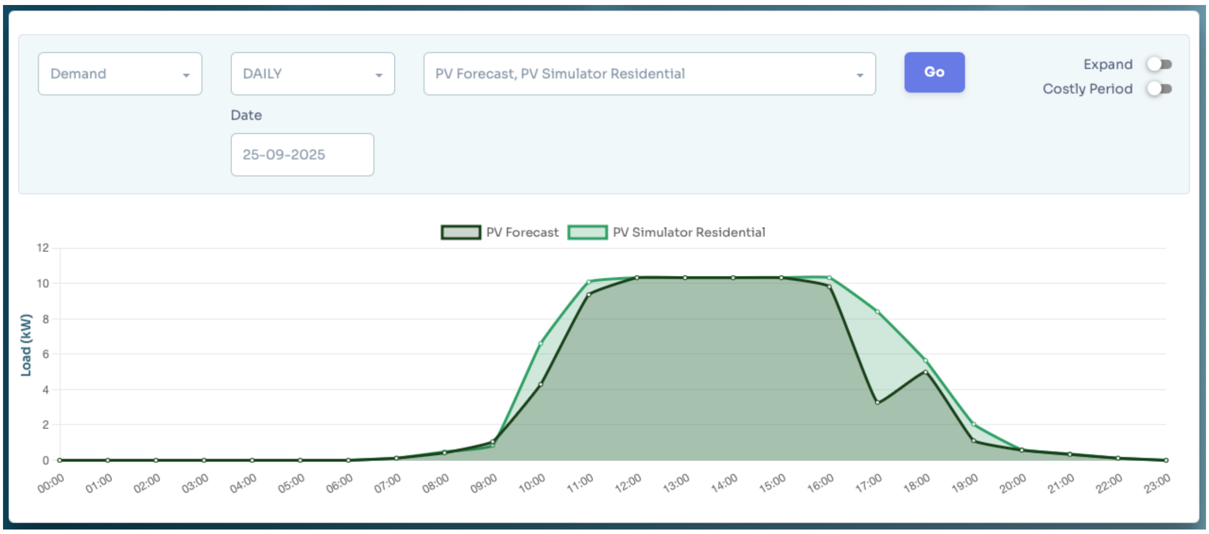


Figure 12 - PV forecast and Residential PV Simulator providing PV actual generation

3.3.3.1. KPI 1 Performance: Renewable Energy Self-Consumption Maximization

Achieved Results

PV-Charging Alignment Analysis:

- **Morning Charging (07:49-10:00)**: Initial charging at 5 kW during early PV generation ramp-up
- **Peak PV Period (10:00-14:00)**: Intensive charging at 10-11 kW coinciding with maximum PV output (~10 kW)
- **Optimal Synchronization**: Charging schedule closely follows PV generation curve profile

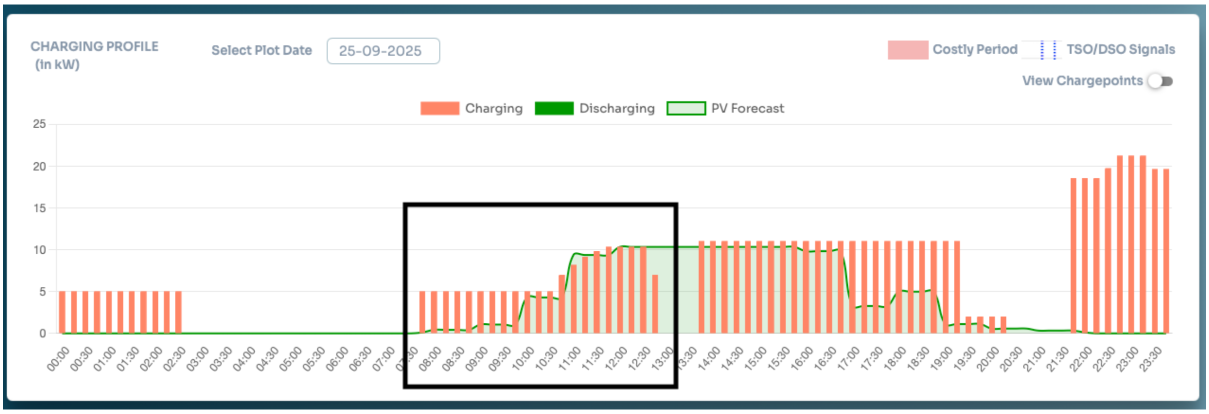


Figure 13 - Charging session showing prioritization of PV for EV charging

Performance Analysis

The system successfully demonstrated renewable energy optimization by:

- **PV Generation Tracking**: Charging power levels dynamically adjusted to match available PV generation
- **Smart Ramping**: Gradual charging increases following PV generation ramp-up pattern
- **Forecast Integration**: Charging schedule pre-optimized based on PV generation forecasting

3.3.3.2. KPI 2 Performance: Grid Dependency Reduction

Achieved Results

Renewable vs. Grid Energy Analysis:

- **High Renewable Periods**: Majority of charging (approximately 70%) occurred during peak PV generation windows
- **Grid Dependency Minimization**: Limited grid energy consumption during low/no PV generation periods. A reduction of 73 kg of CO_{2e} for this charging session calculated via the Well-to-Wheel ratio confirms further the minimization of grid dependency.
- **Load Shifting Success**: Charging concentrated during daytime renewable availability

Performance Analysis

Grid dependency reduction was achieved through:

- **Daytime Concentration**: Charging primarily scheduled during PV generation window
- **Generation-Load Matching**: Charging power levels coordinated with real-time PV output availability
- **Off-Peak Avoidance**: Minimal charging when PV generation was unavailable
- **Renewable Priority**: System prioritized renewable energy periods over lower-cost grid periods

3.3.3.3. System Performance Metrics

Renewable Energy Integration

- **Forecast Accuracy**: PV generation forecasting enabled proactive charging schedule optimization
- **Real-time Adaptation**: System successfully adjusted charging rates based on actual renewable generation
- **Generation Utilization**: High correlation between charging schedule and PV generation availability

Technical Performance

- **Communication Reliability**: All data interfaces (PV forecasting, EMS optimization, charging control) operated without interruption
- **Optimization Responsiveness**: System successfully generated renewable-optimized charging schedules within operational timeframes

User Requirement Fulfillment: Achieved 100% SOC target by 01:48 PM departure while prioritizing renewable energy utilization

3.4. LEC EMS APPLIED TO EV CHARGING PERFORMANCE ANALYSIS

3.4.1. Global results and deviation from plan

Regarding the input data, data for EV charger characteristics and session time came from Trialog simulators and system settings instead of the Bovlabs platform. This is due to the need to use regular charging session data with some control about the time of the sessions that could not be achieved easily using the available chargers from Bovlabs at the time of the demonstration.

All three configuration results were computed following the same charger characteristics and session data. The use case wase applied for a single charger that could reach a maximum power of 22kW.
The baseline was estimated using the default charger management settings corresponding to always charging at the maximum available power at a time while remaining compliant with the charger constraints.

The results were computed based on the demonstration data accumulated for one month (in June 2025). During this time period, 27 charging sessions occurred.

3.4.2. UC 2 Minimization of the consumption peak: local adaptation

3.4.2.1. EMS configuration

The threshold associated with the building consumption for limiting the charger consumption was set to 11% of the max consumption of the building due to an average low consumption from the building considering its maximum.

3.4.2.2. Results

Schedule adaptations depending on building consumption were observed during the demonstration phase.

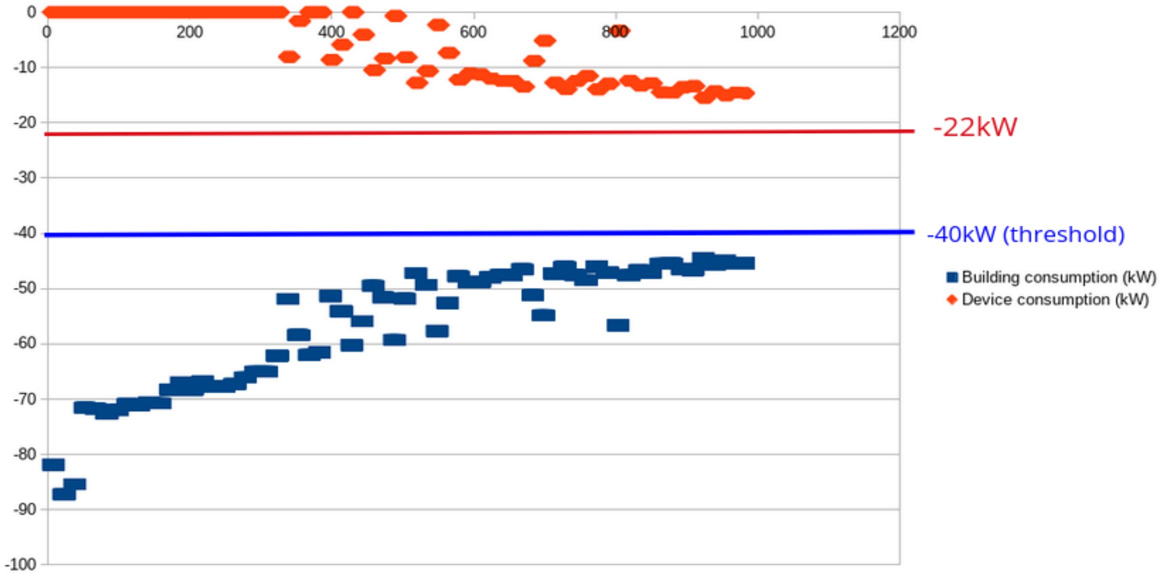


Figure 14 - Schedule adaptation example for LEC EMS (UC 2, local adaptation)

Compared to the default behavior, there is an average of 60% less energy charged per session. It represents a reduction of an average of 52 kWh per charging session

The adaptation was successful, but only with a low threshold to provide results for most of the charging sessions. A higher threshold might be considered if the objective is only to prevent the switch from tripping.

3.4.3. UC 2 Minimization of the consumption peak: adaptation with external signals

3.4.3.1. Configuration

No further system configuration was needed on top of the global settings.

3.4.3.2. Results

Schedule adaptations depending on set points from the flexibility aggregator were observed during the demonstration phase.

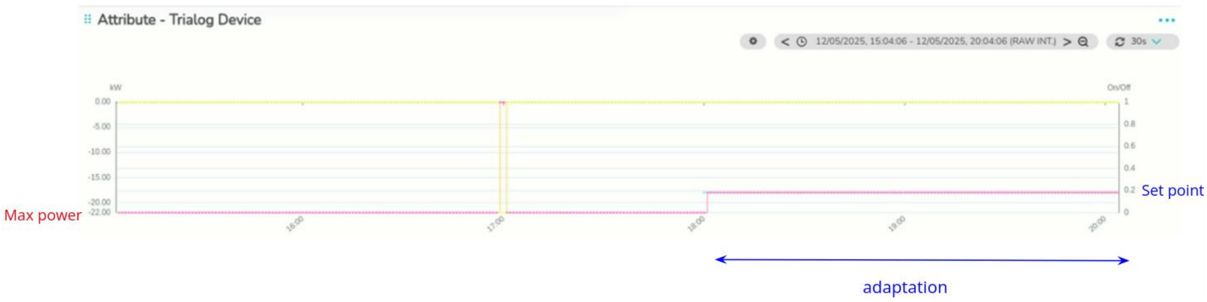


Figure 15 - Schedule adaptation example for LEC EMS (UC 2, external signals)

During the demonstration, 37% of the sessions are concerned by external signals and 27% of these sessions showed a successful adaptation compliant with the external signals. The default behavior was followed 97% of the time during sessions.

The adaptation was proved to possibly be successful, but some errors related to the signals values and system behavior led to inaccurate adaptations. There are also too few adaptations to have a significant difference compared to base line behavior.

3.4.4. UC 3 Maximization of renewable energy sources

3.4.4.1. EMS configuration

The consumption limit was set to 68% of the max power when no PV power was available.

3.4.4.2. Results

Schedule adaptations depending on local PV power generation data were observed during the demonstration phase.

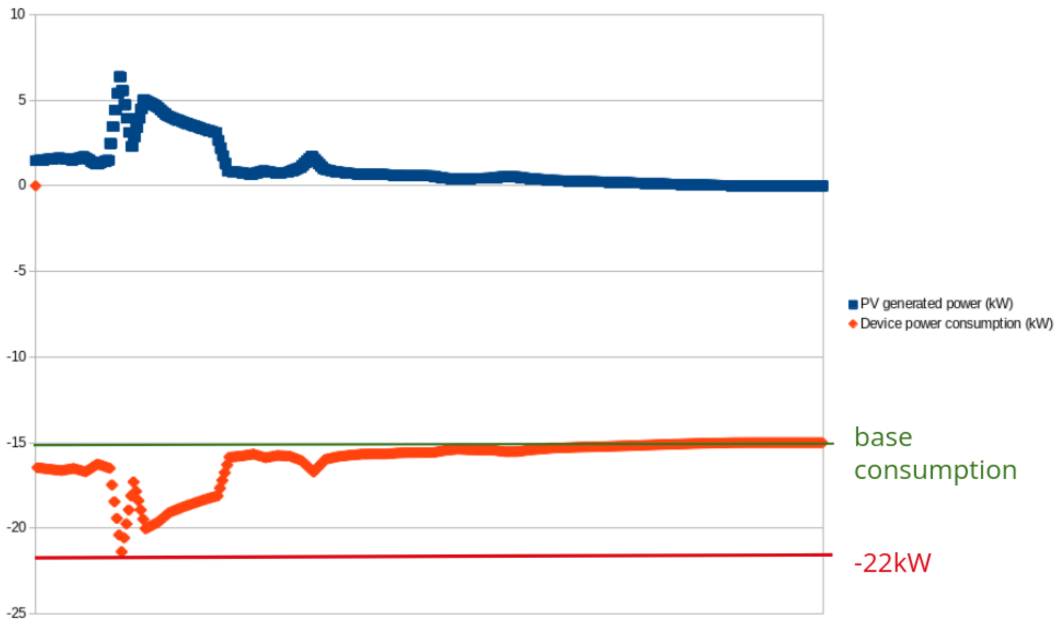


Figure 16 - Schedule adaptation example for LEC EMS (UC 3)

The share of energy charged per session related to PV generation represents on average 25% of the total.

Compared to the default behavior, there is an average of 14% less energy charged per session. The average charged energy per session is equal to ~72 kWh, this is superior to the usual battery capacity (70 kW).

The user needs were satisfied while also performing adaptation base on PV data. The default power when there is no PV generation could have been chosen to be lower.

3.5. FMTP RESULTS AND PERFORMANCE EVALUATION

3.5.1. Analysis of activation performance from FMTP perspective

For the most mature intermediary platform, i.e. the small-scale VPP, we demonstrate the evaluation of the activation performance and flexibility-to-power ratio. Since all values are based on simulated assets, the results have only exemplary character and should not be used for scientific interpretations.

The small-scale VPP simulated an aggregation of PV generators that could provide negative flexibility by curtailment of the generators. The offered negative flexibility was only a minor share of the generation. The VPP did not offer curtailment to 0 kW. Since the communication of setpoints and monitoring data happened in intervals of 2 s over a period of 93 days (from 2025-02-27 to 2025-05-30) there is an enormous amount of data collected in the FMTP's data base. To be able to handle this amount of data efficiently we analyzed the 15 min average values of baseline, flexibility, setpoint, and provisioned activation. The total amount was 8924 intervals of which 4145 intervals (46,4%) showed a total generation above 1 kW. The daily peak generation of the aggregated PV was between 901 kW and 1173 kW.

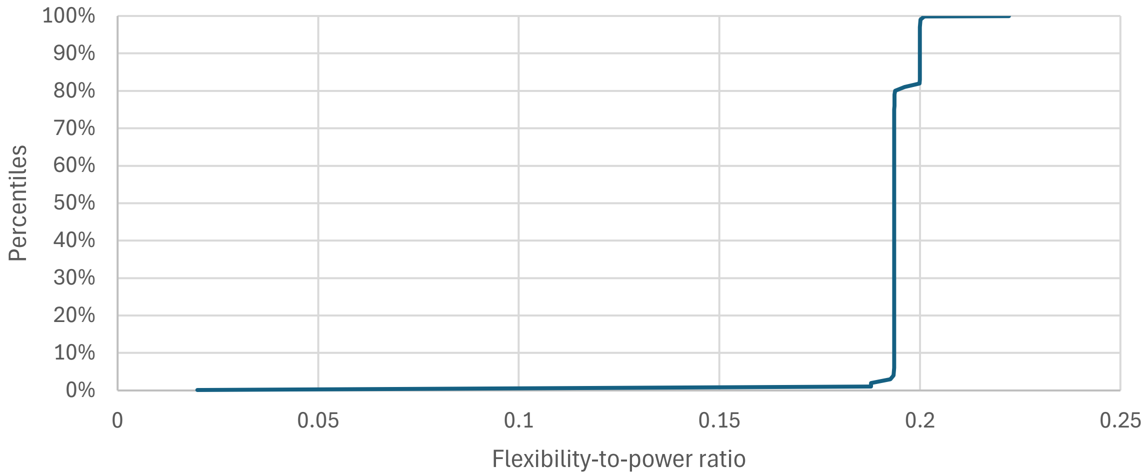


Figure 17 - Distribution of Flexibility-to-power ratio of the small scale VPP for residential PVs

The first analyzed KPI is the “flexibility to power ratio”, i.e. the share of generated active power that the VPP offered as flexibility to the FMTP. The distribution of the KPI is presented in Figure 17. The analysis shows that the VPP offered strictly between 19% and 20% of the generation as negative flexibility. The median of the KPI was 19.36% and the average was 19.44%.

A more meaningful KPI is the activation performance, which represents the ratio of performed curtailment compared to the setpoint sent from the FTMP to the small scale VPP. Figure 18 shows the distribution of this KPI for all activations with a setpoint of at least 20 kW, which occurred during 1690 intervals. Given the fact that a PV inverter can follow a setpoint very fast and accurately, the results seem a bit surprising. 17% of the activations had a performance of approx. 0, or even a negative response, which can be explained by a baseline that is lower than the actual generation. Obviously, the PV did not execute ca. 17% of the received activation setpoints. A deeper analysis shows that all underperformance appeared before 2025-03-12, when Centrica fixed the problem.

As a European standard, an aFRR activation should deliver at least 95% of the setpoint, this criterion was met by 73% of all activation, respectively 97% after 2025-03-12.

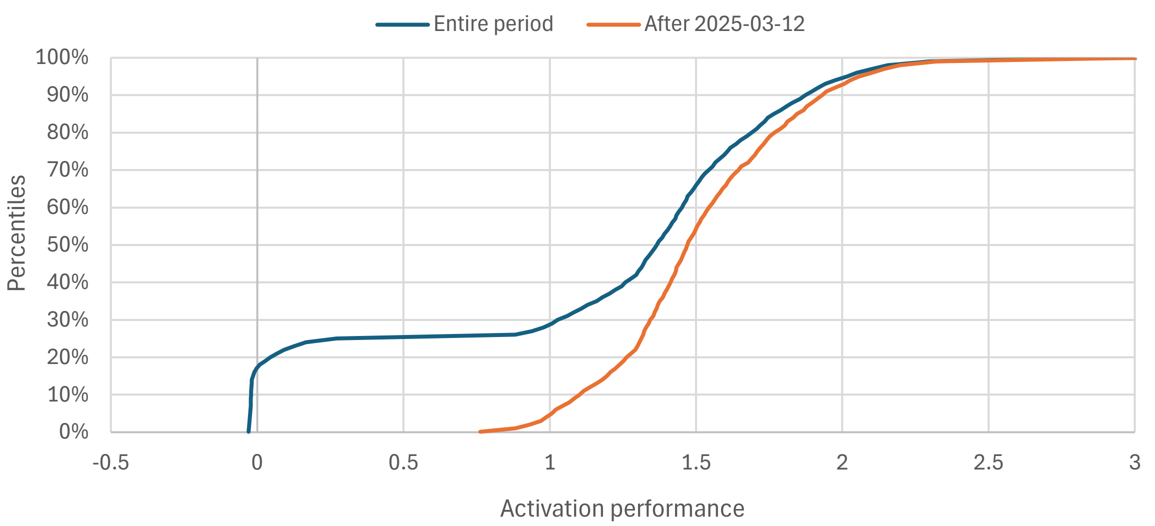


Figure 18 - Activation performance of the of the small scale VPP for residential PVs

The majority of activations showed an overperformance, with a median value of 1.37 (1.47 after 2025-03-12). Activation overperformance is usually tolerated in mFRR markets but should be avoided in aFRR markets. This shows a potential for improvement of the small-scale VPP – a closed-loop control algorithm could most likely improve the activation performance.

This overperformance can also be observed in the monitoring data, as depicted in Figure 19. It can be observed, that in the 15 min interval view the average active power (violet line) is permanently below the setpoint (green line). A more detailed analysis of the data in 1 min intervals, as shown in Figure 20, indicates that the problem may be related to an in average too-high baseline (yellow line), which is in all intervals higher than the active power. The data in 1 min intervals also demonstrate the very fast reaction of the small scale VPP to the received setpoints and the overall high-performant behavior of the small scale VPP.

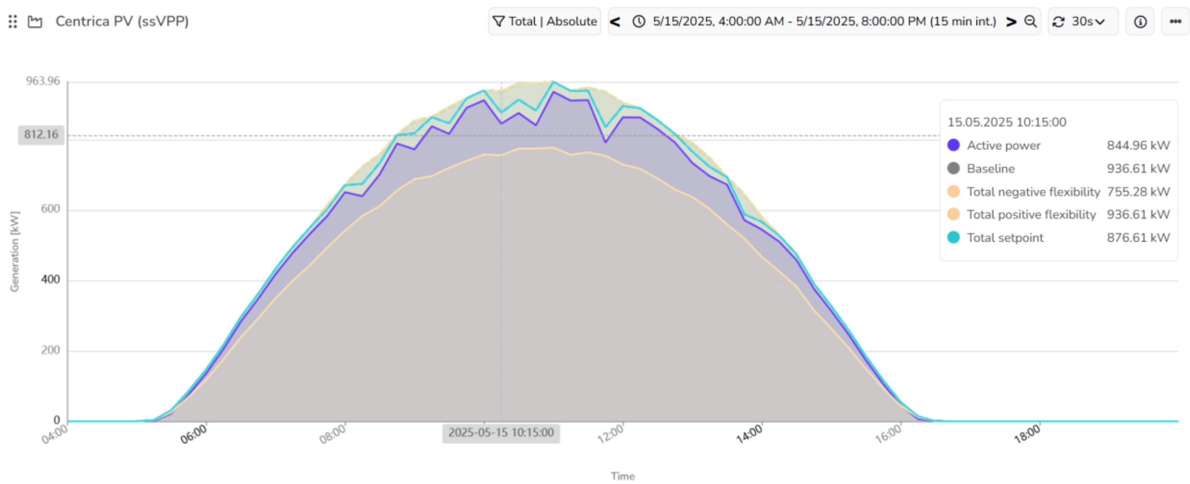


Figure 19 - Example of the aFRR- provision by the small scale VPP (15 min intervals)

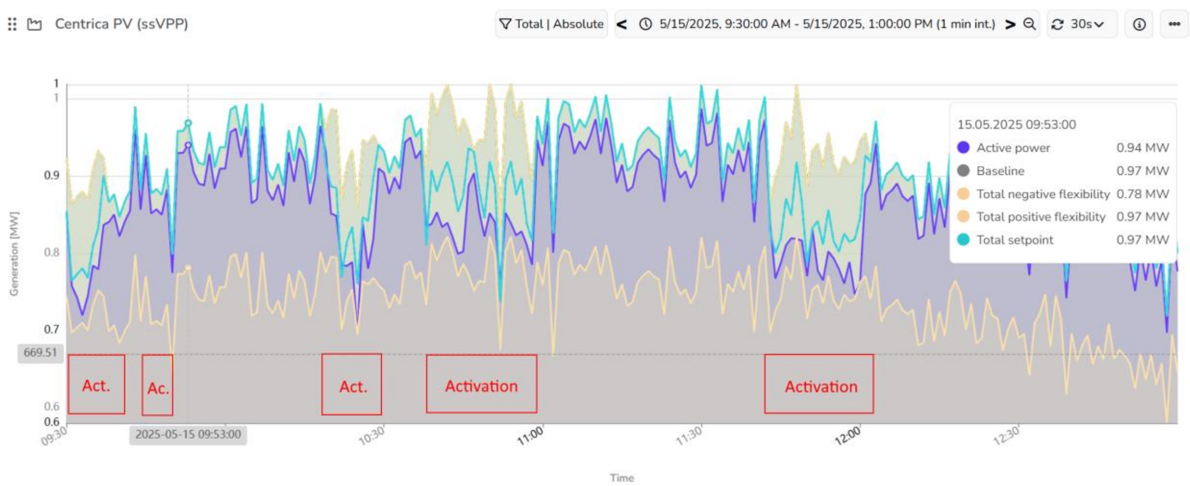


Figure 20 - Example of the aFRR- provision by the small scale VPP (1 min intervals)

3.5.2. Demonstration of practical implementation of use case 2

For the use cases 2 the whole implementation of flexibility offered by the distributed asset, reservation via the FMTP and eventual flexibility activation via the FMTP was successfully tested for approximately 2 weeks. This is shown in the Figure 21 to Figure 24 below. Similar procedures were executed for the platforms of Centrica (UC1) and Bovlabs (UC2).

The Trialog EMS submitted its forecasted consumption baseline (Figure 21) and flexibility (of reduction of consumption, Figure 22) for Peak load reduction to the FMTP. The FMTP reserves the right to curtail the consumption during relevant hours (Figure 23).

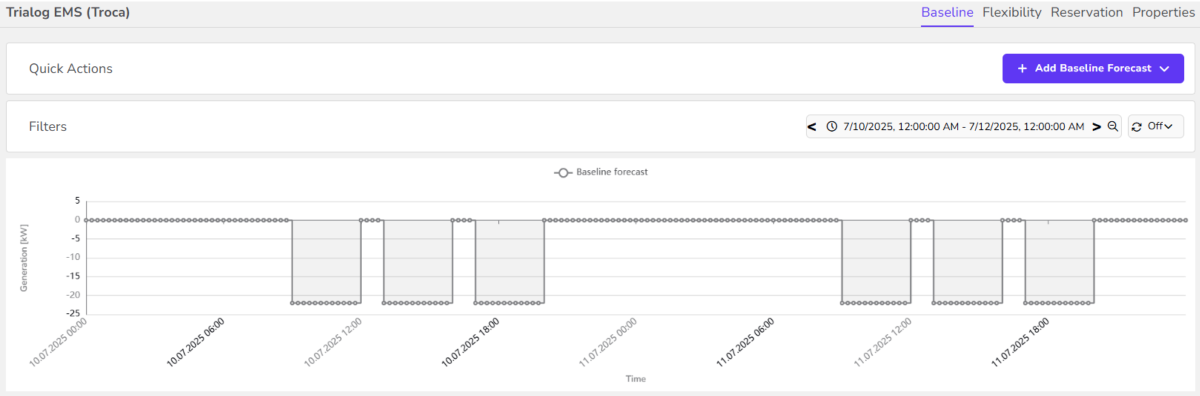


Figure 21 - Baseline of the Trialog EMS received by the FMTP

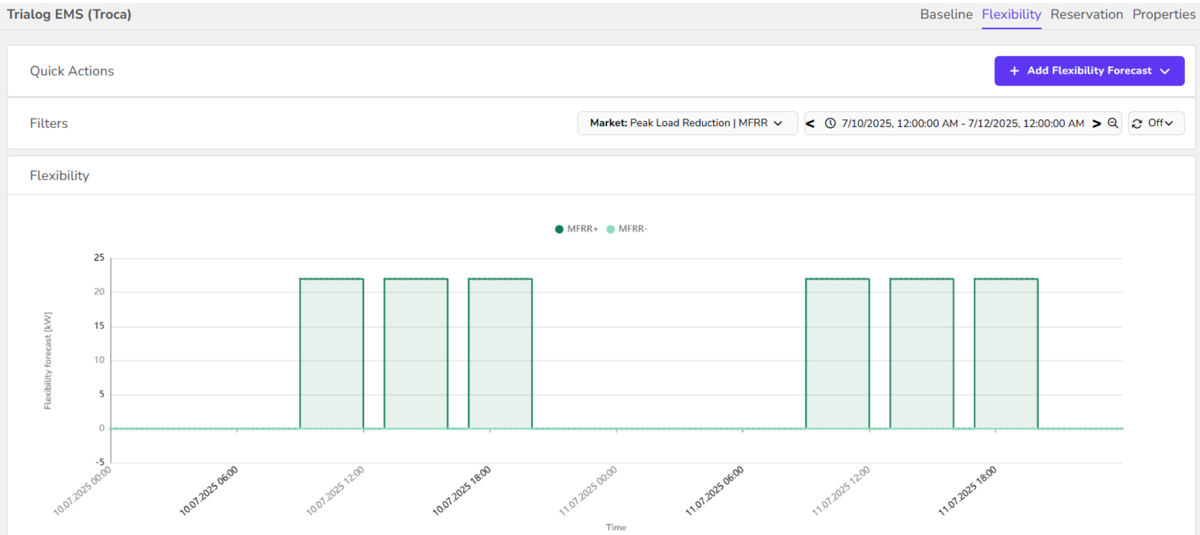


Figure 22 - Flexibility offer of the Trialog EMS received by the FMTP

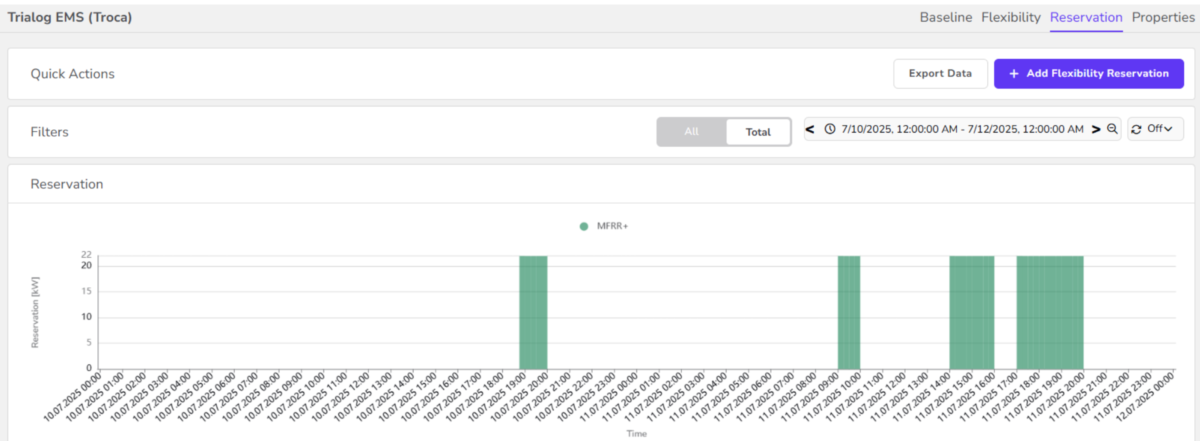


Figure 23 - Flexibilty reservation of the fMTP for the Trialog EMS

If needed by the system operator, the flexibility curtailment is ordered by means of a curtailment schedule as shown in Figure 24. In the shown case the FMTP ordered 2 curtailment activations. The curtailments are indicated by the setpoint (cyan line), while the active power area (violet) represents the real consumption. Activation A with a planned curtailment of 11 kW for timeslot 15:30-15:45 was not performed by the Trialog EMS, but Activation B with a curtailment of 22 kW for timeslot 18:30-19:30 was realized by the EMS, even tough it ended prematurely. The KPIs resulting of the entire series of these test sequences are explained in section 3.4.

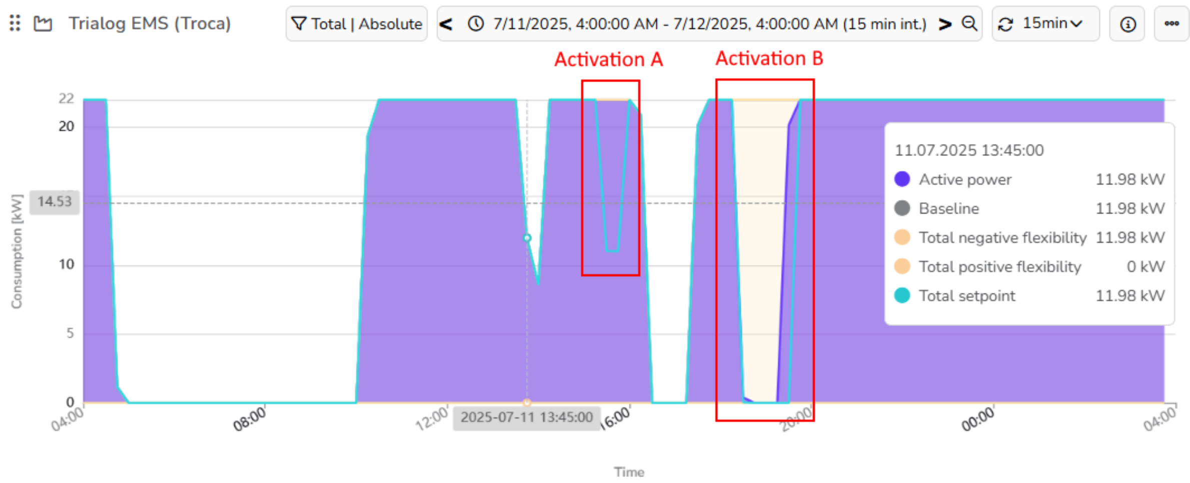


Figure 24 - Flexibility activation requested from the Trialog EMS (Troca)

3.5.3. Demonstration of charge management of a battery

In particular for use case 1, frequency ancillary service provision, batteries will in future play a major role on islands due to the very fast response times and very good controllability of the output power. The disadvantage of batteries is the limited energy storage capacity and it needs special control strategies to deal with that limiting factor. In 2025, the typical ratio of capacity to power of batteries is 2 MWh/MW to 4 MWh/MW. This means that a battery operated to provide symmetrical ancillary services like aFRR must be operated around a medium level of state-of-charge (SOC) in order to be able to perform activations and provide energy in both direction continuously for at least 30 min. The requirements for the maximum duration of activation at full power depends on the pool of assets that provide the ancillary service. If the amount of batteries is low compared to conventional thermal power plants then a short time of service provision of the battery may be acceptable and the other assets can serve as backup during the recharging of the battery. But if batteries play a major role in the ancillary service pool then it is essential that the battery power can be activated all of the time. This con be achieved by active charge management of the batteries. In the WP9 demonstration of MAESHA, we investigated two separate strategies how the battery charge management can be realized.

A) shift the battery baseline depending on SOC
B) perform dedicated recharging activations

Both strategies can be applied in charging and discharging direction. Both strategies were simulated on a battery with 10 MWh and 5 MW that provides aFRR services. The charge management was performed in parallel to aFRR provision, so the battery could continuously provide ancillary services.

The method of shifting the battery baseline as a means to get the SOC to the normal operational range of e.g. 35%-65% is demonstrated in Figure 25. The battery itself doe neither generate nor consume power, therefore the normal baseline is at 0 MW. Because of the low SOC (light grey line) of only 5%, the baseline (dark grey line) was shifted to -200 kW, so in average the battery will charge slowly. This strategy does not require any direct reaction from the dispatcher, because the low power shift is neglectable compared to average load fluctuations. Another advantage is that nearly the full battery capacity (reduced by the baseline shift) is still available for aFRR services. But the low charging power enables only slow recharging, in the figure below it takes nearly 10h to increase the SOC from 7% to 40%. Therefore, this strategy is better suited for power systems where the aFRR demand is rather symmetrical and there are no longer periods on aFRR activation in the same direction.

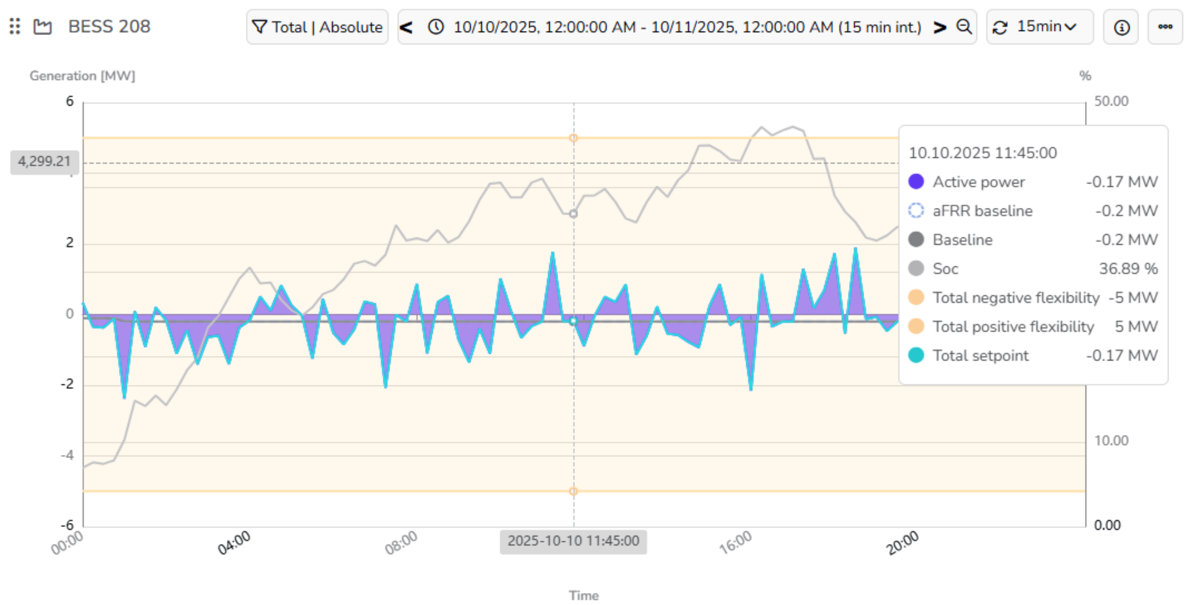


Figure 25 - Battery charge management by baseline shift

The second strategy of recharging the battery via a dedicated recharge activation is demonstrated in Figure 26. In this case a schedule is created that charges the battery in short time, but also requires a power plant to provide the same power simultaneously. This strategy requires a deeper integration of the battery with the generation fleet, e.g. via an established intraday market of a coordinated action of the system operator. In the example shown below, the battery is charged with a schedule (dashed grey line) of 2 MW that lasts from 13:30 to 15:30 with a ramp of ±5 min at the beginning and the end of the schedule. The ramp prevents that the battery charging itself may cause significant frequency deviations.

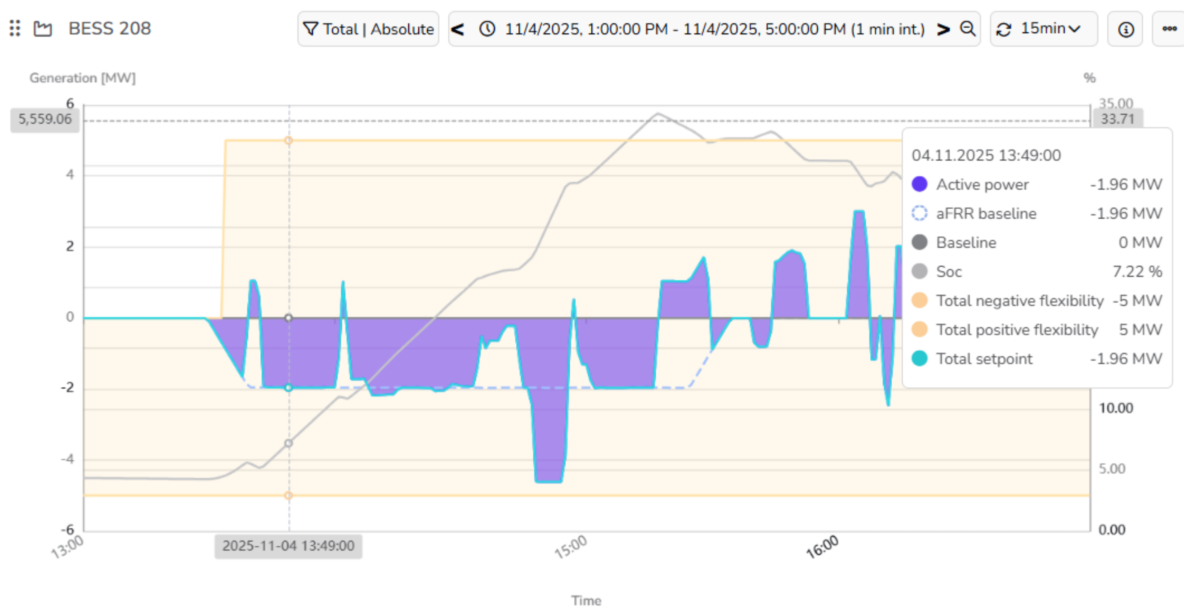


Figure 26 - battery charge management via a recharge activation

The schedule enables a fast recharging of the battery and therefore this strategy is better suited to power systems where the aFRR demand is not symmetrical than the previous strategy. The schedule is also used as the aFRR baseline, which points out the main disadvantage of the scheduled recharging: the battery can offer significantly less power for aFRR in charging direction during the recharging period. In the example shown the battery power available for aFRR- was reduced from 5 MW to 3 MW. At the same time the power for aFRR+ was temporarily increased to 7 MW.

Both strategies and their pros and cons could be demonstrated successfully. Depending on the characteristics of the power system and pool of ancillary services providing assets, the system operator may decide to apply either strategy of a combination of both strategies to maintain the SOC of the batteries used for ancillary services in an appropriate range.

3.5.4. Technical performance of the platform and interfaces

3.5.4.1. Interface performance

The technical performance of the platform and interfaces was evaluated with the KPI Communication availability. This KPI counts all minutes of the day, during which at least one correct measurement value was received. We can express this KPI in percentage or the inverse unavailability in min/week.

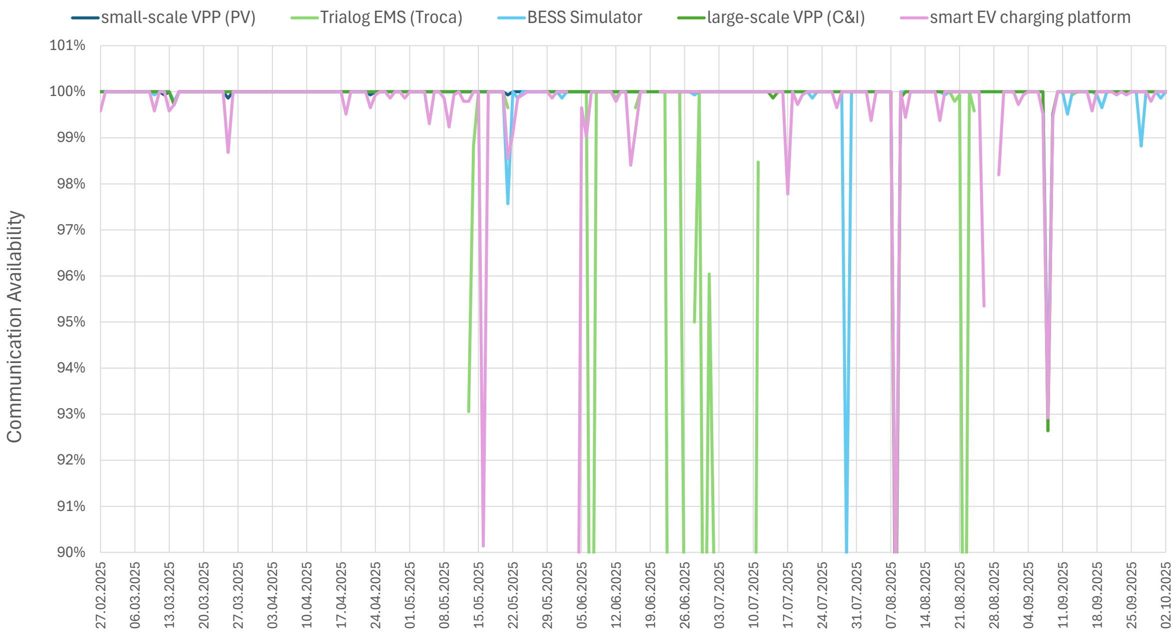


Figure 27 - Evolution of KPI Communication availability

Figure 27 and Table 7 present the detailed values of communication availability. The total availability considers all values, regardless if there was a major system update, like on the 2025-08-07, or if platforms were often only used for some hours per day, like the Trialog EMS. Nevertheless, most interfaces showed an availability of 99% or more. Which demonstrates that even in this demonstration with a low technological readiness level (TRL) a high availability of the FMTP, the intermediary platforms, and their interfaces could be achieved.

In a more accurate analysis of the interface performance, we only considered dates when the components and platforms were planned to be available all day. The results of this analysis are shown in Table 7 with the KPIs "filtered availability" and "unavailability". In this analysis all systems and APIs showed an unavailability of max. 73 min/week. The more mature platforms even reached values below 6 min/week. The best performance showed the small-scale VPP using the MQTT protocol with an unavailability of less than 1 min/week during the observation period of 110 days. Such unavailability levels highlight the feasibility of the platforms to provide aFRR services.

Table 7 – Detail values of communication availability

Component / system	Protocol	Total availability	Filtered availability	Unavailability [min/week]
Small-scale VPP (PV)	mqtt	99.40%	99.99%	0.6
Building Simulator (IEC104)	IEC104	99.80%	99.87%	12.9
Trialog EMS (Troca)	mqtt	52.19%	99.28%	73.0
BESS Simulator	IEC104	99.85%	99.94%	5.8
Small-scale VPP (AC)	mqtt	99.41%	100.00%	0.3
Large-scale VPP (C&I)	IEC104	99.53%	99.96%	4.0
smart EV charging platform	mqtt	98.86%	99.80%	20.4

3.5.4.2. Measured performance and hardware requirements of the FMTP and C&I VPP

The backend of FMTP and C&I VPP includes a dedicated monitoring dashboard designed to ensure operational reliability, resource efficiency, and service availability. This dashboard provides real-time insights into system performance and resource utilization across the deployed infrastructure.

The dashboard serves as a central tool for operators and researchers to monitor the health of core services, track CPU and memory usage at both namespace and cluster levels and analyze network request patterns. These capabilities are essential for identifying potential bottlenecks and ensuring compliance with performance and scalability requirements. A momentary snapshot of the dashboard is illustrated in Figure 28. The dashboard includes time-series graphs illustrating CPU and memory usage by Pod, as well as network request trends. These visualizations allow operators to identify performance anomalies and optimize resource allocation.

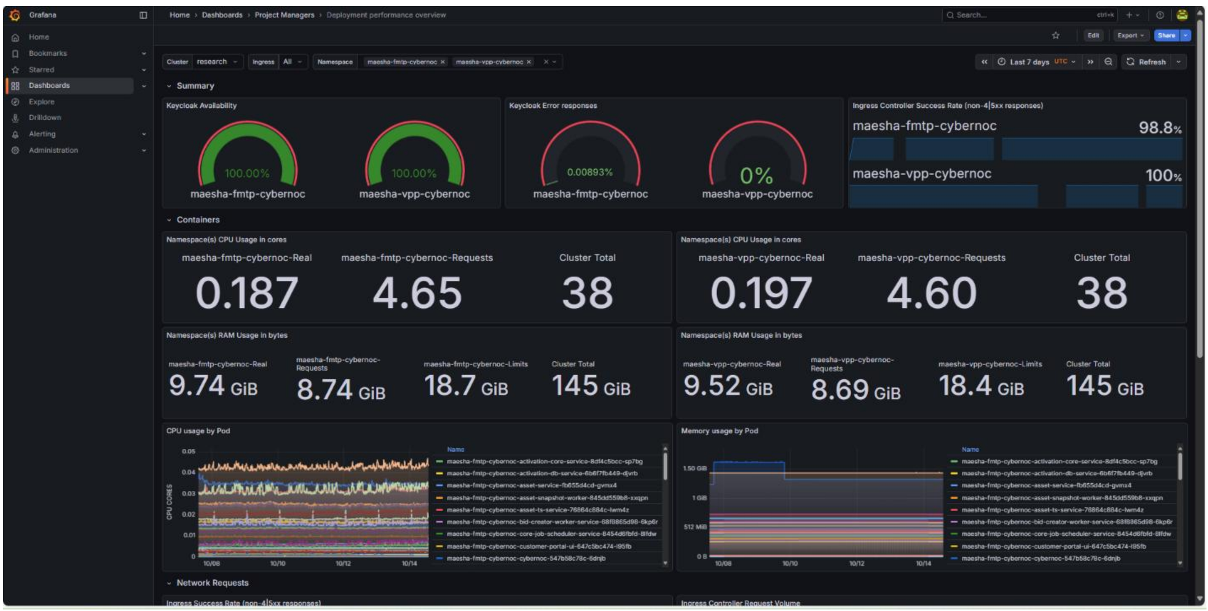


Figure 28 - FMTP resource monitoring dashboard

Key Metrics and Indicators

The dashboard reports several critical metrics. Service availability is monitored through the Keycloak authentication service, which achieved 100% uptime for both maesha-frmtp-cybernoc (FMTP) and maesha-vpp-cybernoc (C&I VPP) namespaces. Error responses were negligible. The ingress controller success rate was similarly high, reaching 98.8% and 100% for the respective namespaces.

Resource utilization is tracked in terms of CPU and memory. For the illustrated snapshot of the dashboard, actual CPU usage was 0.187 cores for maesha-frmtp-cybernoc and 0.197 cores for maesha-vpp-cybernoc, compared to requested allocations of approximately 4.6 cores per namespace. Memory usage followed a similar pattern, with real consumption of 9.74 GiB and 9.52 GiB respectively, against requested allocations of about 8.7 GiB, within a cluster total of 145 GiB.

Interpretation

The graphs indicate that the FMTP and C&I VPP platforms operate within its allocated resources. CPU usage remain significantly below requested limits, suggesting efficient resource allocation and headroom for scaling. The memory usage is ca. 12% above the plan but the increased demand could be handled by the container orchestration system given the total allocated memory in the entire cluster. The high availability of authentication services and near-perfect ingress success rates confirm system stability. Network request patterns show consistent traffic without anomalies, supporting the conclusion that the platform meets its performance KPIs.

3.5.5. Tests with real assets and devices

These tests demonstrated the feasibility of the FMTP to operate not only in simulation environment but also with real assets.

3.5.5.1. Monitoring of EV charging via the smart EV charging platform

On Sept. 11th 2025, a successful end-to-end test of EV charging with an electric vehicle plugged to the charging station at the EDM headquarter in Mayotte was carried out. The FMTP was hosted in the AWS cloud in the Frankfurt region and could receive all measurements without issues. The result is shown in Figure 29.

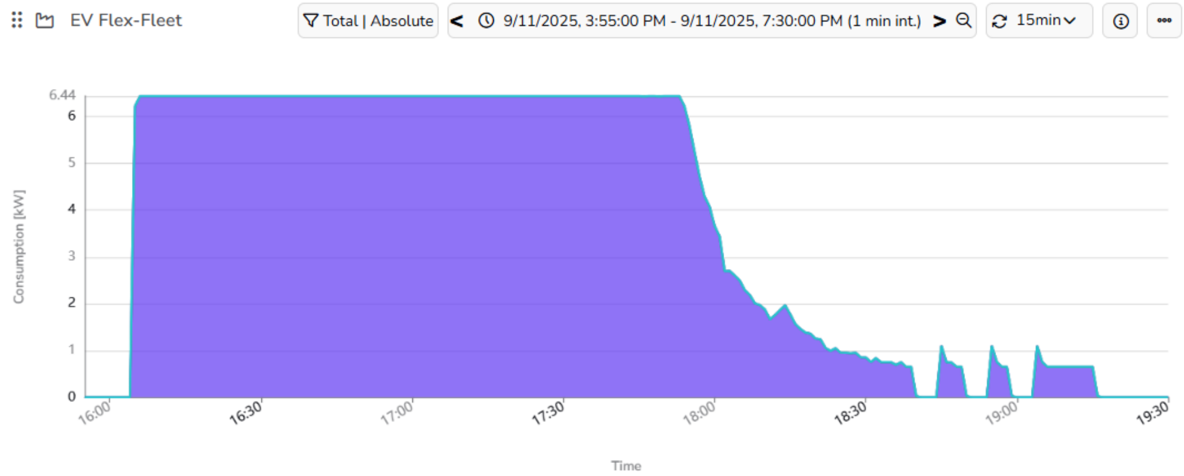


Figure 29 - End-to-end test of EV charging between the EDM headquarter and the FMTP

3.5.5.2. Small battery attached to PV in CyberGrid's lab

This test was used as a long term stability test to investigate the behavior of the C&R RTU under real-life conditions. The power of a battery+PV installation in the lab of CyberGrid in Maria Enzers-dorf, Austria was monitored over several months. Examples are given in Figure 30 and Figure 31.

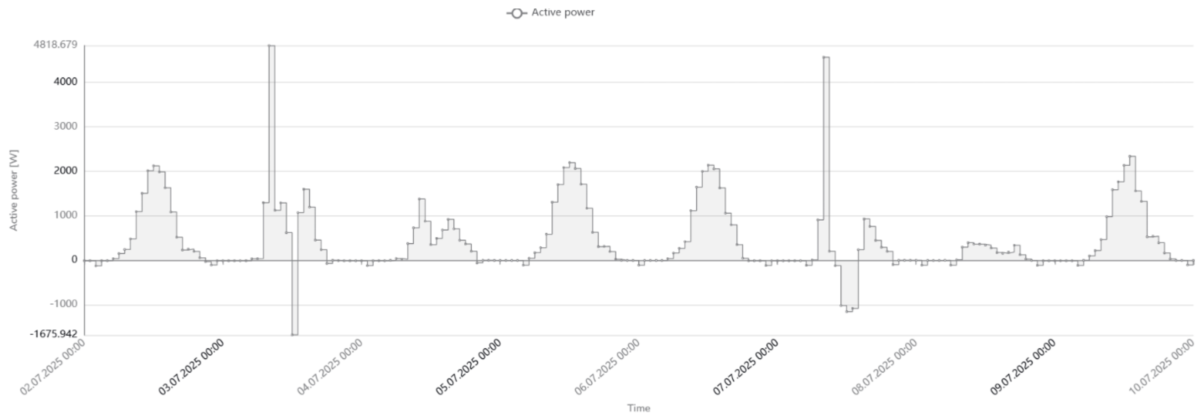


Figure 30 - Exemplary long-term monitoring data of the lab installation of PV and battery

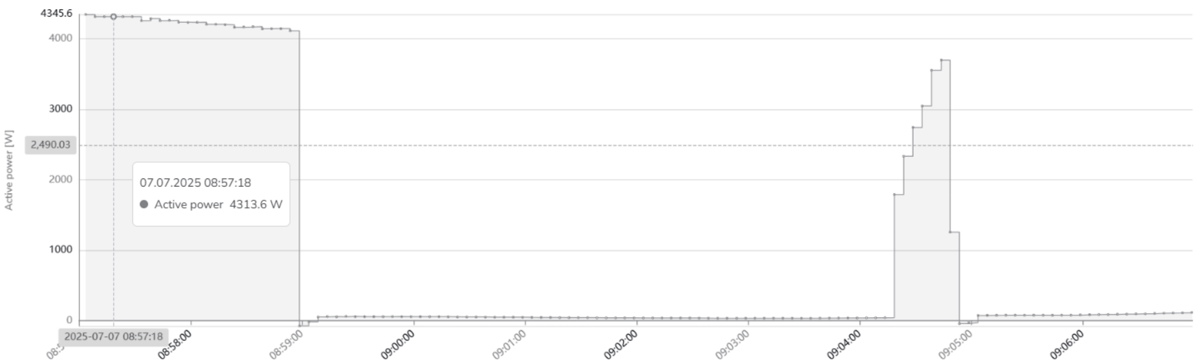


Figure 31 - Monitoring data of the lab installation of PV and battery in the raw interval of 2 s

While the battery and PV inverter proved to be reliable devices, Figure 32 indicates that the prototype of the C&R RTU turned out to be the bottleneck for the system availability. During normal days the mobile communication showed availability of 100%, but the RTU's modem and firmware were very vulnerable to short outages of the mobile connection and re-login was not successful every day. This analysis shows a need for an improvement of features for communication re-establishment of the C&R RTU.

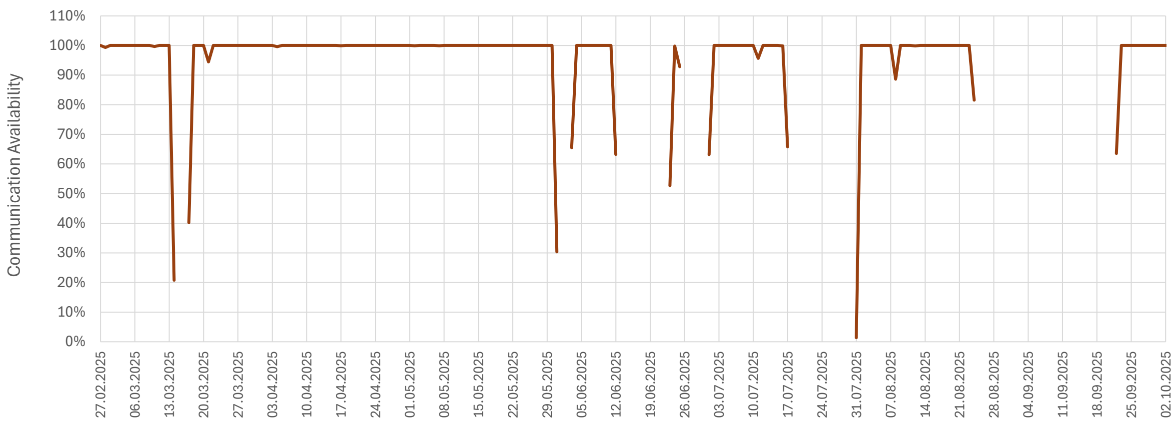


Figure 32 - Communication availability of the C&R RTU prototype in the lab installation

4. Conclusion Of Demonstration Activities

4.1. Recommendations and Optimization

4.1.1. Use Case 1 – Frequency control

The demonstration of downward aFRR service provision with small-scale VPP controlling aggregated solar PV curtailment showed the technical feasibility of this approach. That was proven by high system availability of the small-scale VPP with distributed solar assets.

Given the decarbonisation goals of the islands, the value of solar power will be not only in the low-carbon generation but also in the flexibility-driven curtailment or activations for system balancing. Therefore, it is vital for the newly integrated solar power stations (and existing installations where possible and cost-economical) to have remote controllability and have access to flexibility services.

However, further work must address the challenges related to this approach. While the demonstration conclusions are limited due to a small size and simulated nature of the residential solar PVs, the performance of small-scale VPP showed a difficulty to provide reliable baseline estimation for the aggregated solar production. Therefore, new methods should be explored to provide aggregated forecast of solar power at day-ahead and ultra short term (5 minutes) horizons.

Large-scale VPP with utility battery storage also demonstrated technical maturity for the aFRR service showing high power and system availability. However, around 24% of aFRR activations showed underperformance. To mitigate this in the future, market design can consider reserve power rules for battery storage to manage state-of-energy and provide a reliable aFRR service.

From the perspective of the system operator, it is not sufficient to only have access to fast downward control services, more emphasis must be taken to identify potential for reliable and fast option for upward control. On Mayotte, batteries are the only alternative to conventional generators for provision of upward control services. But the demonstration with a simulated large-scale battery showed clearly the impact of limited energy storage capabilities of the battery. If batteries are used to provide upward control services, the operator must consider measures to maintain the energy content of the battery. Providing symmetrical services, i.e. upward and downward control at the same time, instead of only upward control, can help to recharge the battery during the periods of negative control. Symmetric control services will increase the time during which the battery will be fully available in both directions but cannot avoid a discharge of the battery under all situations. In large power systems with liquid intraday markets, the battery management can avoid extreme charging levels – mainly too low but also too high – by trading energy on the intraday market. For the situation on an island without liquid intraday market the method of permanent recharging of the battery by setting a baseline that in average covers daily stand-by losses and cycle losses proved to be a better method to maintain an average energy level of the battery over the timespan several days and without the need of manual intervention.

4.1.2. Use Case 2 – Minimization of the Consumption Peak

The Minimization of Consumption Peak use case demonstration has been successfully completed, achieving both primary objectives through a single comprehensive 12-hour charging session. The results provide conclusive evidence of the smart charging system's capability to optimize energy consumption while maintaining user convenience and system reliability. The experiment proved that coordinated scheduling can effectively align charging with demand-side objectives, delivering measurable benefits for end-users, utilities, and the grid.

The Bovlabs smart charging demonstration further highlighted its ability to generate strong economic, technical, and operational value. The system achieved a 36.5% cost reduction (€8.23 per session) compared to uncoordinated charging by shifting load away from peak pricing periods, thereby validating its economic proposition. Importantly, residential peak demand was completely avoided, preventing additional grid stress during critical evening and morning cycles. Technical validation confirmed seamless integration across EMS, building simulators, pricing systems, and charging infrastructure, all performing reliably under real-time optimization. These results establish operational readiness, with benefits extending across stakeholders—economic savings for users, infrastructure relief for utilities, and system-wide improvements in stability and renewable integration

The demonstration of Peak Load Reduction service provision with small-scale VPP controlling the cooling of aggregated AC units showed the technical feasibility of this approach. That was proven by high system availability of the VPP. However, the performance analysis of VPP power response to the requested activations highlighted the challenges in estimating the cooling demand baseline. Although only few simulated assets were used in the demo to represent large pool, it is expected that the performance improves for a larger population of assets. Furthermore, while the simulation considered simulated thermal dynamics in the households and used reasonable temperature preferences and occupancy, it's recommended to make a real-life pilot and collect a real-life feedback information from the end-users about thermal comfort to assess the impact of the aggregated AC controls on the end-user thermal comfort.

4.1.3. Use Case 3 – Maximization of Renewable Energy Sources

The Maximization of Renewable Energy Sources use case demonstration has also been successfully completed, meeting its objective of coordinating EV charging with renewable energy availability. Approximately 70% of charging occurred during peak PV generation periods, demonstrating effective synchronization between renewable intermittency and EV flexibility using the Bovlabs platform. Grid dependency was minimized during non-renewable hours by focusing charging during daytime PV windows, thus reducing reliance on conventional generation during evening peak periods. While cost savings were modest at 6.8% (€0.68 per session), the trial emphasized renewable utilization over pure economic optimization, showing that environmental objectives can complement financial benefits

Together, these demonstrations reinforce the system’s comprehensive value proposition. By combining peak demand reduction with renewable energy maximization, the smart charging framework delivers scalable solutions for both grid operators and end-users. It showcases the feasibility of achieving cost efficiency, emissions reduction, and system reliability simultaneously. At scale, adoption of such strategies could flatten demand curves, enhance renewable integration, and reduce infrastructure expansion needs, making smart EV charging a key enabler of sustainable energy transitions.

4.1.4. Use Case 4 – Energy Access

The technical solution to collect consumption and production data and display it to the end user on different hardware devices (computer, mobile phone) has been successfully demonstrated by MAESHA project on simulated data.

To test them in a real environment, our recommendation is that there are already devices communicating on the consumption meters and the production site. This also requires the prior presence of a communication network (GSM, internet or LoRa) covering the entire area of the energy community.

4.2. Lessons Learned, Barriers & Replicability

4.2.1. Use Case 1 – Frequency control

Solar PV assets on Mayotte Island have been unable to participate in system balancing due to strict contractual obligations in power purchase agreements (PPAs) that prioritize maximum power production. However, as the share of wind and solar energy continues to grow, it is increasingly clear that focusing solely on production is no longer sufficient. Mechanisms such as solar PV curtailment can offer greater value to the overall energy system. Therefore, future contractual arrangements should consider grid-aware remuneration mechanisms to support system flexibility and reliability.

Large batteries on Mayotte island are providing ancillary services directly to the system operator EDM. The service and tariffs are regulated in special contracts that are tendered and monitored by the French regulator. All batteries with significant size have a direct connection to the SO's SCADA for telecontrol purposes. Therefore, we could not test the FMTP with such batteries. But the long-term test of the FMTP with simulated batteries and aggregations of simulated assets have demonstrated that the FMTP concept is performing reliably and fast enough to manage external flexibilities even for aFRR services. By means of the FMTP and the demonstrated communication concept the communication between the SO's SCADA and the field assets can avoid the installation of expensive direct lines, i.e. private lines fully decoupled from public networks. This approach shows a significant potential for decreasing costs and time required for integration, in particular for mid-sized batteries and flexibility assets, without compromising the security of the SCADA system. In fact, the number of potential entry points will be reduced by the FMTP. It needs to be evaluated if the national security guidelines for the power industry are ready to support the FMTP communication concept or if a too strict interpretation may provide a barrier for that cost saving potential.

4.2.2. Use Case 2 – Minimization of the Consumption Peak

The connectivity of the Air Conditioning units is one of the challenges for its applications for in peak load reduction. This challenge was overcome in the project using custom setup with the infrared controller, local remote telemetry unit, and additional metering installation. However, such options are not cost effective to scale. It's therefore vital to enable and enforce by regulation a presence of standard cloud-based connectivity with newly installed AC assets of different manufacturers. Given that there are at least 1 million offline air-to-air heat pumps in Europe, and at least half a million are projected to be installed every year, that's one of the urgent priorities.

Regarding the results obtained using Trialog LEC EMS (Troca) in a virtual pilot, implementing the use cases and providing a demonstration proved that adapting EV charging profiles in simulation is possible and can meet the objectives of consumption peak shaving.

For systems like EV chargers, whose usage is difficult to predict by nature, striking a balance between local user expectations and grid operator requirements is a challenging issue. Integrating external adaptation signals linked to market needs and EV schedule management poses challenges in this regard. The market requires reliable power consumption forecasts to send signals, yet EV charger consumption forecasts are inherently unreliable, especially for public chargers.

Unfortunately, the use case could not be demonstrated using real EV user data from Mayotte due to installation issues and low usage. Rather than relying on simulated user behavior, it would be interesting to compare the model with real infrastructure usage.

The Bovlabs demonstration for this use case has generated valuable insights into the load reduction with respect to the peak slots, building consumption, and the DR signal from the FMTP. The system demonstrated high replicability and scalability potential. Its modular, standards-based architecture - leveraging MQTT, REST APIs, OCPP protocols, and cloud storage - ensures adaptability across different environments.

From the perspective of flexibility management and dispatch of medium and small flexibilities the demonstration proved the feasibility of the entire FMTP workflow

a) Distributed assets upload their baseline and flexibility forecasts and cost information to the FMTP
b) FMTP reserves the required amount of flexibility and asset operators can see reservations and prices
c) FMTP dispatched the assets if needed
d) FMTP monitors the asset's activation performance

A barrier for scalability is the number of manual steps needed in this process, which is neither practical nor economic for medium sized assets. In that regard, the scalability of asset integration can be improved by plug-and-play concepts with automatic registration, for which the MQTT protocol seems to be a suitable framework. It also must be considered to replace the daily offering by long-term contracts, where the assets only need to send the flexibility forecasts for the day-ahead but the price shall only be adapted once per month or even once per year. Furthermore, the entire task of flexibility forecasting can be shifted to the FMTP, which will reduce the integration barrier for the distributed energy assets.

4.2.3. Use Case 3 – Maximization of Renewable Energy Sources

Regarding the results obtained using Trialog LEC EMS (Troca) in a virtual pilot, implementing the use cases and providing a demonstration proved that adapting EV charging profiles in simulation is possible and can meet the objectives of maximizing RES usage.

As with the peak shaving use case, it would be interesting to confront this use case with real infrastructure usage instead of just simulated usage. Furthermore, while some use cases are complementary, such as reducing local consumption depending on building consumption and maximizing PV-generated power, others contradict each other. This is particularly true for maximizing RES usage and load balancing at a higher level. For the sake of separating the applications, however, the use cases were applied in separate simulated locations.

In the future, it would be interesting to study the results of implementing more chargers and adding more than one computational objective and compare them with the results obtained here for single-objective computation.

The Bovlabs demonstration generated valuable insights into the implementation of renewable-optimized smart charging, consolidating technical validation, operational experience, and scalability potential. One of the key lessons learned was the reliability of multi-protocol communication, with MQTT and REST APIs enabling seamless, stable exchanges over 12+ hour operations. The EMS successfully integrated diverse data inputs from PV generation, pricing systems, and charging infrastructure without failure. Optimization strategies proved effective, achieving measurable cost savings while maintaining user convenience and grid stability. A minimum-rate charging strategy during peak demand periods emerged as an effective compromise, reducing grid stress while meeting user requirements. Now that all the installed charge points in the island are integrated with the back-end, real-time monitoring of these are possible by EDM using the Bovlabs EMS and CPMS backend points.

Reliance on simulated inputs for PV and building loads reduced the extent of real-world validation. Addressing these issues will enhance robustness for broad-scale application. The approach is highly transferable to island systems with high renewable penetration, where grid constraints make optimization particularly valuable. Scalable extension from single EVs to fleets provides opportunities for demand aggregation, improved renewable integration, and enhanced grid stability. EV charging can also work synergistically with storage systems, making the solution a cornerstone for sustainable mobility and energy transitions.

4.2.4. Use Case 4 – Energy Access

The development of the LEC HMI Tool, dedicated to the end users of the participants of an Energy Community, demonstrated that it is possible to set up an efficient technical solution to collect consumption and production data and display them to the end user on different hardware media (computer, mobile phone). The implementation and test of the solution has been successfully demonstrated on simulated data. It is an effective tool to facilitate Demand/Response actions and create a collective dynamic within an energy community and a neighborhood on the subject of energy impact.

However, the essential prerequisite is that there is sufficient network coverage (GSM, internet or LoRa) in the energy community area and the possibility of installing communication objects on electricity meters and production inverters to be able to implement these efficient software solutions. TECSOL provided many technical details on possible IoT solutions (in D.6.2 deliverable about "Hybridization of PV plant and of EV charging points and PV plant and/or cooling/cold production") to set up the real time collection of both consumption and production data.

In Mayotte, the deployment of smart meters only began last year and was not in place on the Talus de Majicavo site, and we had to work with simulated data. However, on an island where smart meters are already in place, these solutions, tested during the MAESHA project, can be successfully deployed.

5. General Conclusion

Deliverable D9.4 concludes the demonstration activities of the MAESHA project and provides a comprehensive assessment of the performance of the solutions developed. Although the demonstration was conducted in a simulated environment, the results offer a realistic and valuable understanding of how flexibility, demand response, and community energy management can operate in an island power system.

Across the four Use Cases, the analysis confirmed that the MAESHA architecture is technically sound and that the solutions developed can effectively address the main challenges faced by isolated grids such as Mayotte's. Frequency control tests demonstrated that both small-scale and large-scale Virtual Power Plants can deliver stable services, provided that baseline estimation and energy reserve management are carefully handled. The smart charging and peak minimisation scenarios highlighted the potential of demand-side management to optimise energy use while ensuring user comfort and system reliability. The renewable-based EV charging experiments showed that coordinated charging strategies can significantly increase the share of local renewable energy in consumption. Finally, the Local Energy Community use case confirmed that transparent access to energy data and real-time visualisation tools can enhance user awareness and enable collective energy action.

Beyond these results, the performance analysis has highlighted several lessons and recommendations for future work. Reliable forecasting methods, robust communication infrastructure, and consistent data quality remain essential for effective flexibility management. The scalability of the demonstrated solutions will depend on the automation of asset integration, regulatory support for flexibility markets, and the progressive deployment of smart meters and connected devices.

Together, the findings from D9.4 show that MAESHA's approach is viable and adaptable. The tools and methods developed, from the FMTP platform to the EMS and smart charging systems, have proven interoperable, flexible, and transferable. While field validation will be required to confirm some aspects in real conditions, the simulated results already provide strong evidence of technical feasibility and operational coherence.

With this deliverable, Work Package 9 achieves its objectives of demonstrating and evaluating the MAESHA solutions. The insights gained here will directly feed Work Package 10, which will focus on replication and transferability. Through this final step, the experience and knowledge accumulated in Mayotte can serve as a foundation for broader deployment across other European islands, supporting their transition towards cleaner, more resilient, and more autonomous energy systems.