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Electric Vehicles Management for carbon neutrality in Europe

Deliverable D8.6

Lessons learned in Greek Demonstrator and Services/Tools Marketability report

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[1] https://ev4eu.eu/

Executive Summary

This deliverable presents an analysis of the Greek pilot demonstration activities carried out within the EV4EU project, with the objective of extracting key lessons learned and assessing the readiness for the deployment of smart charging and Vehicle-to-Grid (V2G) services. Building upon the results reported in Deliverable D8.5, [1] the report translates the technical and operational outcomes of the pilot into insights related to system performance, stakeholder interaction, business model development, and market conditions.

The Greek pilot focused on the implementation and validation of two flexibility mechanisms: Green Charging (BUC 4) and Flexible Capacity Contracts (BUC 5) [8]. These use cases were designed to demonstrate how electric vehicle (EV) charging can be aligned with grid conditions, either through price-based incentives or direct capacity control. The results confirm the technical feasibility of integrated smart charging systems, including the successful interaction between grid monitoring infrastructure, the Decision Support System (DSS), the O-V2X-MP platform, and charging stations. In both cases, flexibility signals were effectively generated, communicated, and implemented at the charging infrastructure level without disrupting user operation.

Despite this positive technical validation, the pilot highlighted important limitations related to system maturity and real-world impact. The relatively limited number of charging stations and EV users in Greece resulted in a low observable impact on the distribution grid, with flexibility activation mainly tested under controlled or simulated conditions. In addition, challenges related to interoperability, partial implementation of advanced communication standards (e.g., OCPP 2.x, ISO 15118), and the limited availability of V2G-compatible vehicles indicate that the ecosystem is still in a transitional phase.

From an operational perspective, the pilot demonstrated that smart charging services can be delivered in a user-friendly and non-intrusive manner. However, the effectiveness of such services depends on user engagement, the strength of economic incentives, and the design of communication strategies. Furthermore, the coordination between system actors and the allocation of charging capacity under grid constraints introduces additional complexity, particularly in scenarios involving multiple stakeholders.

The business model analysis, based on the Service Business Model Canvas (SBMC), confirms that smart charging and flexibility services are inherently multi-actor and service-oriented, relying on coordinated interactions between DSOs, CPOs, eMSPs, EV users, and technology providers. While value is created through improved grid operation, increased infrastructure utilisation, and enhanced service offerings, the analysis also reveals that value capture mechanisms remain limited. In particular, the absence of mature flexibility markets and dynamic tariff frameworks constrains the development of sustainable revenue streams for all actors.

The deliverable also examines the market and regulatory context, identifying key barriers to deployment. These include the lack of established frameworks for flexibility procurement at the distribution level, unclear rules for V2G operation and energy injection, and the absence of standardised interfaces for communication between system actors. As a result, there is a clear gap between technical capability and market readiness.

Based on these findings, the report provides marketability guidelines and a deployment framework for V2G services. The analysis highlights that V2G should be considered a system-level innovation, requiring the alignment of infrastructure, communication standards, regulatory conditions, and business models. While the pilot confirms the potential of EVs to act as flexible and grid-supporting resources, large-scale deployment will depend on further technological maturity, regulatory support, and the development of market mechanisms.

In conclusion, the Greek pilot demonstrates that smart charging services are technically feasible and operationally viable, while V2G services remain at an early stage of maturity. The transition from pilot-scale validation to widespread adoption will require coordinated efforts across technology, market design, and policy frameworks, supporting the evolution towards more flexible, resilient, and sustainable energy systems.

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Acronyms

AC	Alternating Current
API	Application Programming Interface
BMC	Business Model Canvas
BUC	Business Use Case
CAPEX	Capital Expenditure
CPO	Charging Point Operator
DC	Direct Current
DER	Distributed Energy Resources
DSO	Distribution System Operator
DSS	Decision Support System
DTM	Distribution Transformer Monitoring
DUoS	Distribution Use of System
eMSP	e-Mobility Service Provider
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
KPI	Key Performance Indicator
LV	Low Voltage
MV	Medium Voltage
NB-IoT	Narrowband Internet of Things
OEM	Original Equipment Manufacturer
OCPP	Open Charge Point Protocol
OCPI	Open Charge Point Interface
O-V2X-MP	Open Vehicle-to-Everything Management Platform
PPC	Public Power Corporation (Greece)
PV	Photovoltaic
RES	Renewable Energy Sources
SBMC	Service Business Model Canvas
SoC	State of Charge
TLS	Transport Layer Security
TRL	Technology Readiness Level
V2G	Vehicle-to-Grid
V2X	Vehicle-to-Everything
VPP	Virtual Power Plant

1 Introduction

1.1 Scope and Objectives

This deliverable presents the analysis of the Greek pilot demonstration activities within the EV4EU project, with the aim of extracting key lessons learned and assessing the readiness for the deployment of smart charging and Vehicle-to-Grid (V2G) services. Building upon the results documented in Deliverable D8.5, the report focuses on translating the outcomes of the pilot into structured insights related to technical performance, operational implementation, business models, and market conditions.

The scope of the deliverable includes the evaluation of the demonstration results from a multi-stakeholder perspective, covering the Distribution System Operator (DSO), Charging Point Operators (CPOs), e-mobility Service Providers (eMSPs), and EV users. Particular emphasis is placed on the analysis of the two flexibility mechanisms implemented in the Greek pilot, namely Green Charging (EV4EU - BUC 4) and Flexible Capacity Contracts (EV4EU - BUC 5) [2], examining their functionality, performance, and applicability under real-world conditions.

The main objectives of this deliverable are to:

- analyse the technical and operational performance of the implemented solutions,
- identify key lessons learned and limitations observed during the pilot,
- assess the maturity of enabling technologies and system interoperability,
- evaluate the readiness of the market and regulatory environment for flexibility and V2G services,
- develop and analyse business models using the Service Business Model Canvas (SBMC), and
- provide marketability guidelines and deployment recommendations for scaling up the demonstrated services.

Through this approach, the deliverable aims to bridge the gap between pilot-scale validation and large-scale implementation, supporting the transition towards more flexible, efficient, and sustainable energy systems.

1.2 Relationship with other deliverables

This deliverable builds upon and complements several outputs developed within the EV4EU project, ensuring consistency and continuity across the different work packages.

In particular, Deliverable D8.6 is directly linked to ***Deliverable D8.5 "Analysis of demonstration results in Greek demonstration report"*** [1], which provides the detailed technical and performance evaluation of the Greek pilot demonstration activities. While D8.5 focuses on the analysis of system operation, key performance indicators (KPIs), and validation results, the present deliverable extends this work by extracting lessons learned, assessing system maturity, and translating the findings into business, market, and deployment insights.

Furthermore, the analysis conducted in this report is aligned with ***Deliverable D8.2 "Greek demonstrator start-up report"*** [7], which defines the pilot setup, infrastructure, and monitoring framework, as well as ***Deliverable D8.4 "Services Activation in Greek demonstration report"*** [4], which describes the implementation and integration of the demonstration components. These deliverables provide the technical foundation necessary to interpreting the pilot results and understand system behaviour.

The development of the SBMC is also informed by ***Deliverable D1.4 "Business models centred in the V2X value chain"*** [8], where initial business model concepts and value propositions were introduced.

In this context, D8.6 refines and extends these concepts based on real pilot evidence, enabling a more realistic and validated representation of the business models.

In addition, the analysis of the digital platform and V2X functionalities is supported by ***Deliverable D5.5 "Open V2X Management Platform"*** ([3],[9]), which provides a detailed description of the O-V2X-MP platform and its capabilities. This ensures consistency between the technical architecture and the business model representation.

2 Insights from piloting

This section consolidates the key insights derived from the WP8 demonstration activities conducted in the Greek pilot, as comprehensively analysed in Deliverable *D8.5 "Analysis of demonstration results in the Greek demonstration report*" [1]. It provides a structured overview of the pilot context, including its geographical scope, technological enablers, and implemented business use cases, forming the foundation for the extraction of lessons learned and the assessment of service marketability.

The Greek demonstration constitutes a fully integrated smart charging ecosystem, combining EV charging infrastructure, real-time grid monitoring, advanced forecasting, and digital control platforms. The pilot was implemented in a controlled operational environment, enabling the validation of interoperability between system components while ensuring safe and reliable operation of the distribution network.

These demonstration results provide operational, technical, and behavioural evidence that supports the evaluation of flexibility services and their role in future energy systems.

This section extracts the most relevant elements from D8.5 to support:

- the identification of lessons learned,
- the evaluation of business models,
- and the definition of deployment pathways.

2.1 Pilot context

This section outlines the overall setup of the Greek pilot, including the characteristics of the demonstration area, the enabling infrastructure deployed, and the flexibility-oriented business use cases implemented during the pilot.

The demonstration was designed to evaluate how coordinated EV charging and flexibility services can contribute to grid stability, renewable energy integration, and user-centric energy management.

The demonstration integrates:

- Physical infrastructure (chargers, substations, monitoring devices)
- Digital intelligence (forecasting, DSS)
- Market signals (dynamic tariffs)
- User interaction (via O-V2X-MP platform)

The pilot, therefore represents a system-level demonstration, rather than a purely technological test, enabling the assessment of:

- grid-aware charging,
- flexibility activation,
- and user response to economic signals.

2.1.1 Description of the Pilot Area

The Greek pilot was deployed in the municipality of Koropi, located in the East Attica region within the broader Mesogeia area. This area is of particular importance for electromobility deployment due to its mixed-use characteristics, combining:

- residential zones,
- commercial and industrial activity,

- and major transport corridors connecting Athens with the eastern coastal region and Athens International Airport

The municipality hosts more than 30,000 residents, while the wider region includes one of the main industrial zones of Attica, making it a representative environment for urban and peri-urban EV charging scenarios.

From a grid perspective, the pilot area is supplied by multiple Medium Voltage/Low Voltage (MV/LV) substations, with varying loading conditions and network characteristics. This diversity enabled the evaluation of EV charging impacts under different grid states, including relatively low-loading (over-dimensioned) substations and substations operating closer to critical loading thresholds.

The demonstration therefore, provided a realistic yet controlled environment to assess the interaction between EV charging demand and local distribution grid operation.

2.1.2 Pilot Enablers: Hardware and Software Components

The pilot implementation relied on a multi-layer technological ecosystem, combining hardware infrastructure and advanced software platforms.

2.1.2.1 Charging Infrastructure

The selection and deployment of charging locations in the Koropi pilot were guided by the objective of capturing a representative mix of local mobility patterns, while ensuring practical feasibility in terms of installation and operation. In collaboration with the Municipality of Koropi, five candidate sites were initially identified based on accessibility, expected usage intensity, and spatial coverage. During implementation, four of these locations were ultimately realised and became operational, namely Papasideris Stadium, the 2nd Elementary School, Koropi Municipality, and Platea Eleftherias. In each of the four locations, two charging stations and parking lots were considered.

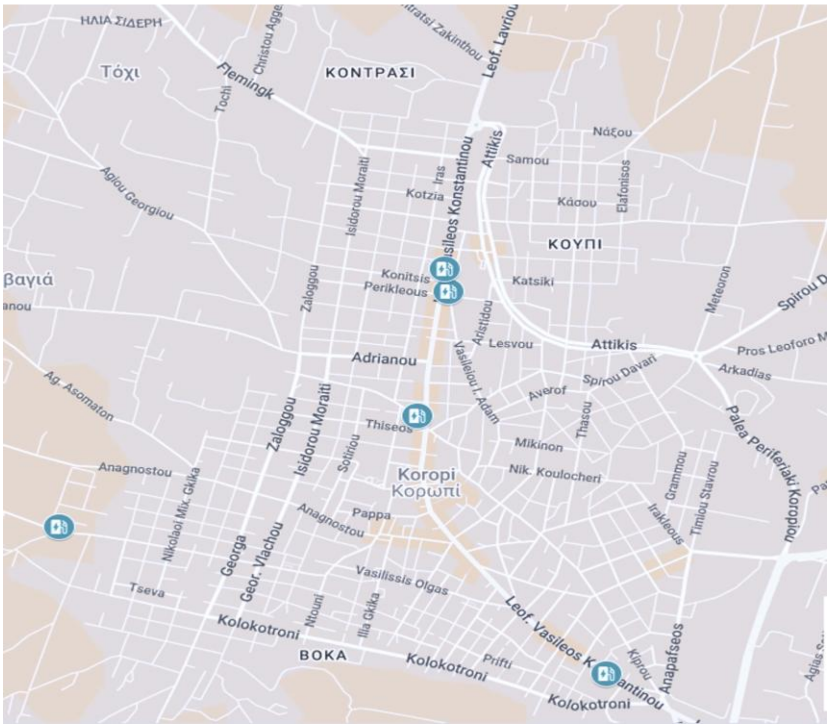


Figure 1: The locations of the 5 charging stations.

The spatial distribution of these sites (**Figure 1)** reflects an intentional attempt to balance different types of urban activity areas, including administrative, educational, and recreational zones. From a lessons-learned perspective, this approach proved valuable in revealing location-dependent utilisation patterns, as charging demand was not evenly distributed but concentrated in specific sites, highlighting the importance of micro-location factors (e.g., accessibility, parking layout, and user convenience) in infrastructure planning.

Each site was equipped with a dual-socket AC charging unit, allowing simultaneous charging of two vehicles. The chargers utilise Type 2 connectors with a maximum power rating of 22 kW per outlet, which was sufficient to support the observed charging behaviour, predominantly characterised by medium-duration, opportunity charging sessions. This confirms that, in similar urban contexts, high-power infrastructure is not always a prerequisite, provided that charger availability and location are optimised [4].

From a system integration standpoint, all charging points were configured to operate under the Open Charge Point Protocol (OCPP) 1.6, enabling seamless communication with the central management platform. This ensured interoperability across system components and supported key functionalities such as real-time monitoring, remote control, and the application of dynamic tariffs. The pilot experience demonstrated that adherence to open communication standards is a critical enabler for scalability, as it allows the integration of heterogeneous hardware and the implementation of advanced smart charging services without vendor lock-in.

The following figure (**Figure 2)** provides indicative images of the deployed infrastructure.

Papasideris Athletics *Agalmatos Square* *Koropi Town Hall*

Eleftherias Square *2nd elementary school.*

Figure 2: Photos of the charging points in the respective areas

As part of the pilot preparation, PPC deployed two distinct V2G-capable charging systems to explore the technical feasibility of bidirectional energy exchange between electric vehicles and the distribution network. The selected equipment, i.e., Enovates Wallbox 22 kW and Wallbox Quasar, represents two fundamentally different technological approaches to V2G implementation, enabling a comparative assessment of AC- and DC-based solutions within the pilot framework **(Figure 3**).

Enovates Wallbox 22 kW V2G

Wallbox Quasar V2G

Figure 3: Procured V2G chargers

From an architectural perspective, the two chargers differ significantly in both charging methodology and intended use cases. The Enovates unit operates under an AC Mode 3 configuration, using a Type 2 interface and supporting three-phase charging up to 22 kW. This makes it suitable for semi-public or commercial environments where higher power levels and compatibility with standard European charging infrastructure are required. In contrast, the Wallbox Quasar employs a DC bidirectional architecture using a CHAdeMO connector, enabling true V2G operation by allowing controlled energy discharge from the vehicle back to the grid. Its lower power rating (5 kW) and single-phase operation position it primarily for residential or pilot-scale applications [4].

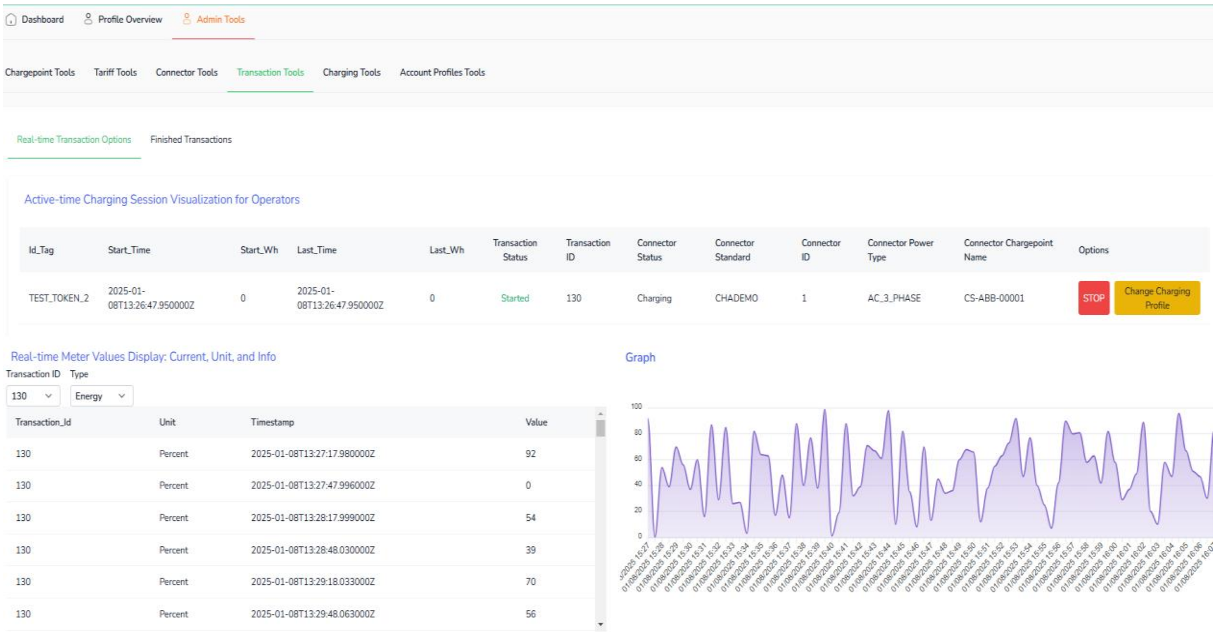
Both devices support interoperability through the Open Charge Point Protocol (OCPP 1.6), ensuring integration with the central management platform and enabling functionalities such as remote control, transaction handling, and smart charging execution. The Wallbox Quasar additionally incorporates user-oriented communication features (Wi-Fi, Ethernet, RFID, app-based control), reflecting its positioning closer to end-user interaction.

An important observation relates to protocol evolution and readiness. While the Enovates charger is designed to support OCPP 2.0.1, offering enhanced capabilities such as advanced smart charging, improved cybersecurity, and compatibility with ISO 15118, this functionality was not activated during the demonstration period. This highlights a broader lesson from the pilot: the availability of advanced standards does not necessarily translate into immediate deploy-ability, due to gaps in commercial readiness and ecosystem alignment.

Overall, the deployment of these two V2G chargers provided valuable insights into the current maturity of bidirectional charging technologies. While both systems demonstrated technical capability at the hardware level, their limited operational use within the pilot further confirms that V2G deployment is currently constrained at first by technology itself but also by regulatory, market, and interoperability challenges.

2.1.2.2 O-V2X Management Platform

The O-V2X-MP platform [5] constitutes the operational backbone of the Greek pilot, enabling the coordinated management of EV charging infrastructure while supporting the implementation of grid-responsive services. Within the EV4EU framework, the platform functions as a central orchestration layer, linking EV users, charging infrastructure, and distribution system operations into a unified digital environment. Rather than acting solely as a charging management system, O-V2X-MP was designed to facilitate the interaction between price signals, user behaviour, and grid conditions. In this context, it plays a key role in translating grid-related inputs, originating from the DSS, into actionable charging strategies applied at the level of individual charging sessions.



Active-time Charging Session Visualization for Operators

Id_Tag	Start_Time	Start_Wh	Last_Time	Last_Wh	Transaction Status	Transaction ID	Connector Status	Connector Standard	Connector ID	Connector Power Type	Connector Chargepoint Name	Options
TEST_TOKEN_2	2025-01-08T13:26:47.950000Z	0	2025-01-08T13:26:47.950000Z	0	Started	130	Charging	CHADEMO	1	AC_3_PHASE	CS-ABB-00001	STOP Change Charging Profile

Real-time Meter Values Display: Current, Unit, and Info

Transaction ID: 130
Type: Energy

Transaction_Id	Unit	Timestamp	Value
130	Percent	2025-01-08T13:27:17.980000Z	92
130	Percent	2025-01-08T13:27:47.996000Z	0
130	Percent	2025-01-08T13:28:17.999000Z	54
130	Percent	2025-01-08T13:28:48.030000Z	39
130	Percent	2025-01-08T13:29:18.033000Z	70
130	Percent	2025-01-08T13:29:48.063000Z	56

Figure 4. Indicative O-V2X-MP screenshot (Transaction Tool) reporting the status of charging sessions in real-time along with the delivered energy over time [5]

From a technical standpoint, the platform follows a modular and service-oriented architecture, based on microservices and interoperable APIs. This design enables flexible deployment and ensures compatibility with a wide range of charging hardware. Communication with charging stations is achieved through OCPP, while real-time data exchange is supported via persistent communication channels, allowing continuous updates on charger status, energy flows, and user interactions. The integration with the DSS enables dynamic responsiveness to grid conditions, forming a closed control loop between monitoring, decision-making, and execution.

The functionalities of the platform extend across several operational layers. At the infrastructure level, it provides full visibility and control over charging assets, including remote session management, tariff configuration, and monitoring of energy transactions. At the system level, it enables the implementation of smart charging strategies, such as load shifting, dynamic pricing, and capacity-based limitations, directly linked to grid requirements.

A critical feature of the platform is its ability to support real-time interaction with users. Through its frontend interface, users are informed about charging conditions, tariff variations, and potential constraints, while also being provided with tools for locating chargers, managing sessions, and accessing historical data. This interaction layer proved essential for ensuring user awareness and engagement, particularly when flexibility actions were applied.

In addition, the platform incorporates data analytics and forecasting capabilities, allowing the estimation of charging demand at station level. These predictive functions complement the DSS by providing insights from the demand side, supporting more effective planning and operation of charging infrastructure.

From a lessons-learned perspective, the pilot highlighted that the effectiveness of smart charging services depends heavily on the presence of a robust and flexible digital platform capable of integrating multiple stakeholders and system layers. The modular architecture of O-V2X-MP proved advantageous in accommodating evolving requirements and integrating external components. At the same time, the experience underscored the importance of:

- seamless interoperability with charging hardware,
- reliable real-time communication,
- and clear user-centric functionalities to ensure acceptance of grid-driven interventions.

Overall, the O-V2X-MP platform enabled the practical realisation of the pilot's business use cases, demonstrating that digital coordination is a key enabler for scaling smart charging and future V2G services, provided that it is supported by mature standards, stable communication, and user-centric design.

2.1.2.3 LV network monitoring

The deployment of the low-voltage (LV) monitoring system constituted a critical component of the Greek pilot, enabling both enhanced grid observability and data-driven network management. The primary objective was to establish a detailed and reliable measurement framework capable of capturing real-time grid conditions and supporting the integration of electromobility through informed operational decisions [4].

Figure 5: LV monitoring installation

The monitoring infrastructure was designed to provide high-resolution measurements of key electrical parameters at the substation level, including voltage, current, frequency, active and reactive power, energy consumption, and harmonic distortion. This level of granularity allowed for a comprehensive assessment of grid behaviour under EV charging conditions and enabled the evaluation of demand response and flexibility scenarios.

From an implementation perspective, each monitored substation was equipped with a combination of metering devices installed at both the LV busbars and the outgoing feeders. Specifically, three-phase meters based on Rogowski coil technology were deployed to measure current flows, while voltage measurements were obtained through appropriately installed sensing clamps at the busbar level. This configuration ensured accurate and non-intrusive monitoring of electrical quantities across the network.

Communication and data acquisition were supported through NB-IoT technology, with each device equipped with embedded SIM connectivity and local storage capabilities. This allowed continuous data transmission to the central platform, while also ensuring resilience in case of temporary communication loss. The selected solution, provided by the Greek company Meazon, enabled scalable and cost-effective monitoring aligned with the needs of distribution system operators.

In total, five MV/LV substations supplying the pilot charging infrastructure were instrumented. Each substation included one main meter at the LV busbar, complemented by multiple feeder-level meters, resulting in a total of 32 monitoring points across the network. This setup provided sufficient visibility to analyse load distribution, identify potential bottlenecks, and assess the localised impact of EV charging.

To further enhance monitoring capabilities, an additional layer of instrumentation was deployed through a Distribution Transformer Monitoring (DTM) solution provided by Itron[4]. This complementary system included transformer-level monitoring devices and feeder-level measurement units, as well as outage detection functionalities. The integration of this secondary system enabled cross-validation of data and provided additional insights into grid reliability and fault conditions.

From a lessons-learned perspective, the pilot clearly demonstrated that high-resolution LV monitoring is a fundamental prerequisite for enabling smart charging and flexibility services. The availability of real-time and historical data proved essential for:

- validating grid constraints,
- supporting forecasting models,
- and triggering flexibility mechanisms.

At the same time, the deployment highlighted practical considerations for large-scale roll-out, including:

- installation complexity at existing substations,
- communication reliability in field conditions,
- and the need to balance measurement granularity with cost efficiency.

Overall, the monitoring system provided the necessary visibility to transition from passive grid operation to active, data-driven management, which is a key requirement for the large-scale integration of EVs and advanced flexibility services.

2.1.2.4 DSS Overview

The Decision Support System (DSS) deployed in the Greek pilot ([2],[4]) represents the central intelligence layer enabling the coordinated operation of grid monitoring infrastructure and EV charging services. Rather than functioning as a standalone tool, the DSS was designed as an integrated environment that aggregates data from multiple sources and translates it into actionable information for grid management and flexibility activation.

At its core, the DSS establishes a functional link between three key elements: the distribution network monitoring infrastructure, the operational systems of the Distribution System Operator (DSO), and the charging management platform (O-V2X-MP). Through this integration, the system enables continuous data exchange and event-driven interactions, allowing grid conditions to directly influence charging behaviour.

The primary role of the DSS within the pilot was to enhance situational awareness and support decision-making processes. By combining real-time measurements from the LV monitoring system with forecasting outputs, the DSS was able to identify potential grid constraints, such as transformer overloading or voltage deviations, and generate corresponding control signals. These signals were then communicated to the O-V2X-MP platform, which executed the appropriate smart charging or flexibility actions in line with the defined business use cases.

From an architectural perspective, the DSS operates as a modular software platform capable of hosting multiple functionalities and interfacing with external systems and field devices. This modularity proved essential for accommodating heterogeneous data sources and enabling interoperability across the different components of the pilot ecosystem.

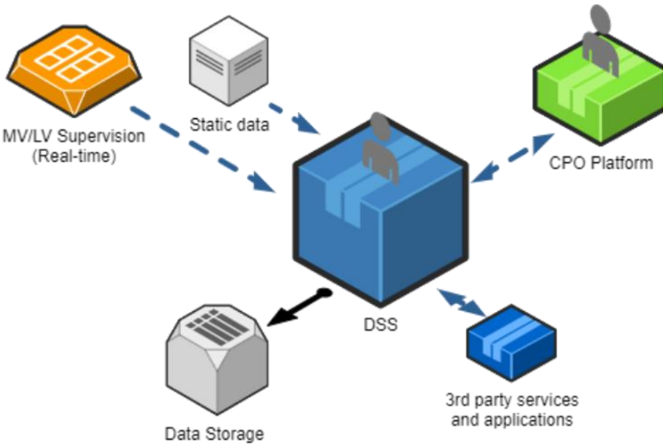


Figure 6: DSS architecture

A key insight from the demonstration is that the value of the DSS lies not only in data aggregation, but in its ability to translate grid conditions into operational actions. The pilot confirmed that effective flexibility services require a tightly coupled interaction between monitoring, analytics, and control layers, with the DSS acting as the coordination hub.

At the same time, the implementation highlighted several practical considerations. The integration of different systems required alignment at both technical and semantic levels, particularly in terms of communication protocols and data models. Moreover, the effectiveness of the DSS was directly dependent on the quality and availability of input data, reinforcing the importance of reliable monitoring infrastructure and accurate forecasting.

Overall, the DSS enabled a transition from passive grid observation to active, informed system management, supporting the real-time coordination of EV charging with network conditions. This capability is essential for scaling up flexibility services and represents a key building block for future smart grid architectures.

2.1.2.5 Forecasting and Monitoring

Within the Greek pilot, a dedicated framework was developed to support the anticipation of grid conditions and the timely activation of flexibility services. This framework combines real-time monitoring data with short-term forecasting techniques, enabling a proactive rather than reactive approach to grid management [4].

The implemented solution relies on continuously collected measurements from the LV monitoring system, which are aggregated on an hourly basis and used as input for a short-term forecasting model. The model operates on a rolling horizon of four hours, updating its predictions every hour to reflect the most recent system conditions. This approach allows the system to maintain an up-to-date view of expected transformer loading and potential constraint violations.

A key component of the framework is the mechanism used to determine when flexibility actions should be triggered. Instead of relying on simple threshold exceedance, a weighted trigger function was introduced to assess the severity and persistence of predicted violations. This function evaluates deviations from operational limits across the forecasting horizon, assigning higher importance to near-term predictions while accounting for increasing uncertainty further into the forecast window.

To enhance robustness, the triggering logic incorporates a hybrid decision approach. In addition to direct forecast values, it considers probabilistic bounds derived from the forecasting model, particularly when operating close to critical limits. This design helps balance the trade-off between unnecessary activations (false positives) and missed events (false negatives), which is essential for maintaining both grid reliability and user acceptance.

Based on the outcome of this evaluation, the system activates the appropriate flexibility mechanism, either through tariff-based incentives or through direct capacity constraints. From a lessons-learned perspective, the pilot demonstrated that forecast-based flexibility activation significantly enhances the effectiveness of smart charging strategies. At the same time, it highlighted the importance of:

- combining deterministic and probabilistic approaches,
- continuously updating predictions,
- and carefully designing trigger logic to avoid excessive or insufficient interventions.

Overall, the forecasting and monitoring framework proved to be a critical enabler for transitioning from static grid operation to anticipatory, data-driven flexibility management, which is essential for scaling such services in real-world distribution networks.

2.2 Business use cases

The increasing penetration of electric vehicles and distributed renewable energy sources introduces new operational complexities for distribution networks [6]. These include higher variability in demand, localised congestion, and voltage management challenges, particularly in low-voltage grids with significant photovoltaic (PV) generation.

To address these challenges, the Greek pilot explored flexibility mechanisms that enable a more dynamic interaction between EV charging demand and grid conditions. These mechanisms rely on the ability to influence charging behaviour either through economic incentives (e.g., dynamic tariffs) or through direct technical constraints (e.g., capacity limits). Within this context, two complementary business use cases were implemented: Green Charging (EV4EU-BUC 4) and Flexible Capacity Contracts (EV4EU-BUC 5) [8].

Both use cases are built on the premise that EV charging can act as a controllable load and potentially a distributed energy resource, provided that appropriate coordination mechanisms are in place. A key feature of the pilot design is the adoption of a monopsony-based market structure, where the DSO procures flexibility services from the CPO, enabling grid-oriented control of charging behaviour at the substation level.

2.2.1 EV4EU-BUC 4: Green Charging

The Green Charging use case focuses on aligning EV charging demand with the availability of renewable energy, while mitigating potential grid disturbances such as overvoltage caused by excess generation [4], [6]. The objective is to encourage EV users to charge during periods of high renewable output, thereby improving local energy balancing and increasing the utilisation of clean energy.

The operational logic of BUC 4 is based on a combination of forecast-driven grid assessment and dynamic pricing signals. Using the DSS, the DSO identifies substations where high renewable injection may lead to voltage deviations. Instead of directly restricting charging, the system incentivises demand through the introduction of favourable tariff conditions, such as reduced or even negative Distribution Use of System (DUoS) charges, making charging more economically attractive during these periods.

At the same time, safeguards are applied to limit excessive reverse power flows. In particular, V2G activity can be constrained when necessary to prevent additional stress on the grid. This dual mechanism ensures that demand is shifted toward periods of surplus generation without introducing new operational risks.

Once these conditions are determined, the DSS communicates the relevant signals to the O-V2X-MP platform, which applies the updated tariffs and operational constraints at the charging station level. End users are informed through the platform interface, allowing them to adjust their charging behaviour accordingly.

From the pilot experience, a key insight is that price-based incentives can effectively influence charging behaviour, particularly when clearly communicated and aligned with user expectations. However, their effectiveness depends on user engagement and the magnitude of the economic signal. The results also indicate that Green Charging is particularly well-suited for environments with high renewable penetration, where it can significantly contribute to local energy balancing.

2.2.2 EV4EU-BUC 5: Flexible Capacity Contracts

The Flexible Capacity Contracts use case addresses a different type of grid challenge, namely network congestion and thermal overloading of infrastructure. In this case, the objective is to ensure that EV charging demand remains within the technical limits of the distribution network, particularly during peak load conditions [1].

Unlike BUC 4, which primarily relies on incentives, BUC 5 introduces a more direct control mechanism based on pre-arranged capacity limitation agreements between the DSO and the CPO. When potential congestion is identified, either through real-time monitoring or short-term forecasting, the DSO activates these contracts, imposing limits on the available charging power capacity at specific substations.

In parallel, dynamic tariff adjustments are applied to reinforce the desired behaviour, typically increasing DUoS charges to discourage charging during constrained periods. These signals are transmitted via the DSS to the O-V2X-MP platform, which enforces the corresponding power limits at the charging infrastructure level and updates pricing information for users.

The platform communicates these changes in real time, allowing users to adapt their charging sessions based on available capacity and cost conditions. This ensures that grid constraints are respected without fully interrupting service, maintaining a balance between system reliability and user convenience.

A key lesson from the implementation of BUC 5 is that direct capacity control mechanisms provide a reliable and effective means of managing grid constraints, especially in situations where price signals alone may not be sufficient. At the same time, their acceptance depends on transparency and user awareness, as well as on the predictability of interventions.

2.3 Limitations and Assumptions

The interpretation of the results obtained from the Greek pilot must be considered in light of some limitations and boundary conditions that influenced both the design and the execution of the demonstration activities. These factors are essential for correctly contextualising the findings presented in Deliverable D8.5 [1] and for assessing the transferability of the results to larger-scale or fully commercial deployments.

- **Scale and Representativeness**

The pilot was implemented at a relatively small scale, involving four operational charging locations and a limited number of active users (13 participants). While this setup enabled controlled testing and validation of system functionalities, it does not fully capture the diversity and complexity of large-scale EV adoption scenarios. In particular:

- charging demand patterns were relatively stable and predictable,
- user diversity was limited,
- and peak load conditions were not representative of high EV penetration environments.

As a result, the observed system behaviour should be interpreted as indicative rather than exhaustive. Nevertheless, the controlled scale of the pilot provided a valuable environment for validating system interoperability, testing flexibility mechanisms, and generating high-quality operational data under well-defined conditions.

- **Absence of Real Grid Stress Conditions**

A key limitation of the pilot was the lack of naturally occurring grid congestion or critical voltage violations during the demonstration period. Although the monitoring infrastructure confirmed variations in substation loading, the network did not experience conditions that would require frequent or sustained activation of flexibility services.

To address this, artificial triggering mechanisms were introduced within the DSS framework to simulate grid stress scenarios and validate the response of the system. While this approach enabled functional testing of the flexibility use cases, it does not fully replicate real-world operational conditions, where constraints emerge dynamically and may involve higher uncertainty and variability.

However, this controlled activation approach allowed systematic validation of flexibility strategies and ensured that all service functionalities were thoroughly tested despite the absence of real constraints.

- **Limited Deployment of V2G Functionality**

Although V2G-capable hardware was installed within the pilot, bidirectional operation was not activated under real conditions. This was primarily due to:

- the absence of commercially available and certified V2G-compatible vehicles,
- regulatory constraints related to energy injection into the grid,
- and the lack of established market mechanisms for compensating V2G services.

As a result, all V2G-related assessments were conducted through simulation. While these simulations provide valuable insights into potential system benefits, they rely on assumptions that may differ from real-world behaviour. Despite this limitation, the combination of real infrastructure deployment and simulation-based analysis provided valuable insights into the technical feasibility and potential system-level benefits of V2G services.

- **User Behaviour and Engagement**

The pilot was conducted with a pre-selected group of users operating within a controlled environment. While user feedback was highly positive, the behavioural responses observed may not fully reflect those of a broader and more heterogeneous user base.

In particular:

- users were aware of their participation in a pilot project,

- charging decisions were not solely driven by economic incentives,
- and the frequency of interaction with dynamic tariffs was limited.

This implies that the responsiveness of users to pricing signals and flexibility mechanisms may differ under real market conditions, where convenience, habits, and competing priorities play a more significant role. Nevertheless, the pilot offered important initial evidence on user acceptance, usability of the platform, and responsiveness to smart charging functionalities, which are critical for future large-scale adoption.

- **Regulatory and Market Constraints**

The pilot operated in an environment where key regulatory and market frameworks are not yet fully developed, particularly with respect to:

- flexibility procurement at the distribution level,
- dynamic network tariffs,
- and V2G participation in energy markets.

As a result, several mechanisms implemented in the pilot, such as dynamic DUoS tariffs or capacity limitation contracts, were applied in a simulated or experimental manner, rather than under fully regulated conditions. At the same time, this experimental setup enabled the exploration of innovative market designs and highlighted concrete regulatory gaps, providing valuable input for future policy development.

- **Data and Forecasting Assumptions**

The forecasting framework relied on historical monitoring data and short-term prediction models, with demonstrated accuracy within the pilot context. However, forecasting performance is inherently dependent on:

- data quality and availability,
- system variability,
- and the scale of deployment.

Under higher penetration scenarios, increased uncertainty and more volatile demand patterns may affect prediction accuracy and, consequently, the effectiveness of trigger-based flexibility activation. Nevertheless, the pilot successfully demonstrated the applicability of forecasting-driven flexibility activation and validated its potential as a key enabler for proactive grid management.

2.4 Key Findings from Demonstration Activities

This section presents a structured synthesis of the main outcomes of the Greek pilot, drawing on both real-world demonstration data and simulation-based analyses reported in Deliverable D8.5 [1]. Rather than reproducing the full set of results, the focus here is on extracting the most relevant quantitative findings and interpreting them in the context of system performance, grid impact, and user behaviour.

The demonstration validated the operation of a fully integrated smart charging ecosystem, combining real-time grid monitoring, forecasting and decision support tools, and a digital platform enabling user interaction and service execution. Across all components, the system exhibited a high level of technical performance and reliability. In particular, the platform operated with full availability throughout the demonstration period, ensuring uninterrupted service delivery, while the data acquisition system achieved an accuracy exceeding 99.5%, supporting reliable monitoring and analytics. In addition, communication between system components was characterised by low latency, in the order of 250 milliseconds, enabling near real-time responsiveness to grid conditions.

From an operational perspective, the pilot recorded a total of 39 charging sessions, corresponding to an overall energy delivery of 548.75 kWh. The average energy per session was approximately 14.07 kWh, indicating moderate utilisation levels consistent with early-stage deployment of public charging infrastructure.

The following subsections analyse these results from two complementary perspectives, focusing first on grid-level performance at the substation level and subsequently on user behaviour and charging patterns.

2.4.1 Key Findings at Substation Level

The analysis at the substation level provides important insights into the interaction between EV charging demand and distribution grid operation, as well as into the effectiveness of the monitoring, forecasting, and control mechanisms implemented in the pilot.

Transformer loading remained within acceptable operational limits throughout the demonstration period. The highest utilisation levels were observed at substations serving areas with increased local activity, reaching values close to 70–75% of nominal transformer capacity. This indicates that, under the current level of EV penetration, the existing distribution infrastructure is capable of accommodating additional charging demand without requiring immediate reinforcement. At the same time, the variation in loading across different substations highlights the importance of the spatial distribution of charging demand, as certain locations exhibited significantly higher utilisation compared to others.

In terms of voltage behaviour, measurements collected at the low-voltage level confirmed that the network operated within acceptable regulatory limits. No significant overvoltage or undervoltage events were recorded during the pilot, despite the presence of distributed renewable generation in the area. This suggests that, at the current scale of deployment, EV charging does not introduce adverse impacts on voltage stability. However, the monitoring system captured variations that indicate potential risks under future scenarios with higher levels of electrification and renewable penetration.

The forecasting framework demonstrated a high level of accuracy, achieving an MAPE of approximately 8.41%. The model operated on a rolling horizon of four hours, updating predictions on an hourly basis using real-time monitoring data. This approach enabled the system to maintain an up-to-date estimation of transformer loading and potential constraint violations. The achieved accuracy confirms that short-term forecasting can effectively support anticipatory grid management and can be reliably integrated into operational decision-making processes.

Although real grid stress conditions were not observed during the pilot, the implemented triggering mechanism allowed the activation of flexibility services under controlled scenarios. This enabled the validation of both tariff-based incentives (BUC 4) and capacity limitation strategies (BUC 5), as well as the communication between the DSS and the O-V2X-MP platform. The system demonstrated fast response times, in the order of a few hundred milliseconds, ensuring that control signals were transmitted and executed efficiently.

Overall, the substation-level analysis confirms that the pilot successfully demonstrated the transition from passive grid monitoring to active and predictive grid management. The combined use of real-time data, forecasting tools, and coordinated control mechanisms enables the identification of potential issues and the application of corrective actions in a timely manner. While the full value of these capabilities will become more evident under higher grid stress conditions, their technical readiness has been clearly validated.

2.4.2 Analysis of Charging Sessions

The analysis of charging sessions provides insights into user behaviour, infrastructure utilisation, and the interaction between end-users and smart charging services.

During the demonstration period, a total of 39 charging sessions were recorded, resulting in a cumulative energy delivery of 548.75 kWh. The average energy per session was approximately 14.07kWh, indicating that users predominantly engaged in partial or opportunity charging rather than full battery charging. This behaviour is consistent with typical urban charging patterns, where users tend to charge their vehicles for shorter durations during daily activities rather than relying on single, full charging events.

Charging activity was not uniformly distributed among users or locations. A relatively small group of active users accounted for a significant share of the sessions, reflecting a common pattern in early-stage deployments where usage is driven by a core group of frequent users. In addition, certain charging locations exhibited higher utilisation levels, suggesting that local context, accessibility, and user routines play a key role in shaping demand.

User feedback collected during the pilot indicates a high level of satisfaction, with an average rating of 4.74 out of 5. This confirms that the charging infrastructure and associated digital platform were well received and that the overall user experience was positive. Importantly, flexibility mechanisms were implemented in a non-intrusive manner, as no charging sessions were interrupted. Instead, control actions were applied through modulation of charging power, ensuring that users could continue their sessions without disruption.

The interaction between users and smart charging services provides additional insights. Although the impact of dynamic tariffs on behaviour was somewhat limited due to the absence of significant grid constraints, the pilot demonstrated that users are receptive to price signals when these are clearly communicated. The results suggest that the effectiveness of such mechanisms will increase under conditions with greater variability in tariffs and more pronounced economic incentives.

Overall, the analysis of charging sessions confirms that user behaviour is compatible with the implementation of smart charging strategies, provided that these are designed in a user-centric manner. Transparency, reliability, and minimal disruption are key factors for ensuring acceptance and engagement. The pilot demonstrates that digital platforms can successfully mediate the interaction between users and grid-driven services, providing a solid foundation for future large-scale deployment.

3 Lessons learned from the demonstration activities

This section presents the key lessons learned from the Greek pilot, building upon the results and insights analysed in Deliverable D8.5 [1]. The objective is to move beyond the evaluation of system performance and to extract actionable knowledge that can support future deployment, replication, and scaling of smart charging and V2G services.

The lessons learned are structured across four main dimensions, namely technical maturity, operational implementation, market and regulatory conditions, and user acceptance. Particular emphasis is placed on identifying the enabling factors and remaining barriers for the real-world deployment of flexibility services and V2G concepts at the distribution level.

The Greek pilot, despite its controlled scale, provided a fully integrated testing environment combining grid monitoring, forecasting, digital platforms, and EV charging infrastructure. This allowed the validation not only of individual components, but also of the end-to-end system behaviour, which is critical for assessing readiness for real-world applications.

3.1 Technical and Operational Lessons

The Greek pilot provided a comprehensive evaluation of the technical maturity of smart charging and flexibility services, covering system integration, platform performance, forecasting capabilities, and the readiness of enabling technologies such as V2G. The demonstration allowed not only the validation of individual components, but also the assessment of the end-to-end system behaviour, which is essential for real-world deployment.

3.1.1 System Integration and Platform Performance

A key positive outcome of the pilot is the confirmation that integrated smart charging systems are technically feasible and operationally stable. The interaction between the O-V2X-MP platform, the DSS, the LV monitoring infrastructure, and the charging stations was successfully established, forming a complete operational loop from data acquisition to control execution. The system demonstrated high availability, low latency, and reliable communication, indicating that such architectures are capable of supporting real-time services.

However, the implementation also revealed that system integration remains a complex and resource-intensive process. Although standard protocols such as OCPP were used, achieving full interoperability required additional configuration, testing, and alignment between components. Differences in data models, communication logic, and vendor-specific implementations introduced integration challenges that required manual intervention.

A particularly important finding concerns the limited maturity of OCPP 2.0.1 in real-world deployments. While OCPP 2.0.1 introduces advanced functionalities (e.g., improved smart charging, device management, and enhanced security), its adoption by commercial charging infrastructure vendors remains partial and inconsistent. In practice, many deployed charging stations still rely on OCPP 1.6 or implement only a subset of OCPP 2.0.1 features. This creates a fragmented environment where advanced capabilities cannot be fully utilised. Furthermore, OCPP 2.0.1 can be seen as a transitional protocol, with ongoing evolution towards OCPP 2.1, which aims to address existing gaps and better align with emerging requirements such as ISO 15118 integration and bidirectional charging.

In addition, the pilot highlighted the absence of a fully standardised interface between DSO and CPO. While internal platform communication (e.g., between DSS and O-V2X-MP) was successfully implemented, there is no universally adopted protocol governing DSO–CPO interactions for flexibility services. Several candidate standards and approaches exist, such as IEC 61850 (for grid communication and substation automation), OpenADR (for demand response signalling), USEF framework (for flexibility market roles and interactions), and emerging APIs/platform-specific solutions, but none are currently widely adopted or harmonised across stakeholders. As a result, integration often relies on custom interfaces or project-specific adaptations, limiting scalability and replicability.

Lessons learned: while interoperability is technically achievable, it is not yet plug-and-play. The ecosystem is still in a transitional phase, characterised by evolving standards, partial implementations, and a lack of harmonised interfaces, particularly at the DSO–CPO boundary. Scaling such systems will therefore require:

- stronger standardisation and alignment across protocols,
- wider and more consistent implementation of OCPP 2.x by vendors,
- and the definition of clear, interoperable interfaces for flexibility service exchange.

3.1.2 Monitoring Infrastructure and Data Availability

The pilot confirmed that LV monitoring is a fundamental prerequisite for deploying grid-aware smart charging services. Large-scale roll-out will require careful attention to installation complexity, communication reliability, data completeness, and cost efficiency, especially when monitoring needs to be extended across many substations and feeders.

Lessons learned: The pilot implementation of the O-V2X platform provided key operational insights for deployment from the DSO perspective. While individual components operated reliably, end-to-end performance depended strongly on coordination, data exchange, and interaction between forecasting, decision-making actions, and flexibility mechanism implementation. Operational constraints such as data delays, missing values, and customer comfort requirements occasionally might affect the effective flexibility available. These highlight the importance of robust monitoring and fallback procedures.

3.1.3 Forecasting and Predictive Control

Short-term forecasting constitutes a critical component of the pilot's operational framework, enabling the anticipation of grid conditions and the proactive activation of flexibility mechanisms. Within the Greek pilot, forecasting was tightly integrated with monitoring data and decision-support tools, supporting near real-time control of EV charging in response to expected network conditions.

Lessons learned: The pilot highlighted that reliable short-term forecasting for operational use benefits from stable and interpretable models. Although more complex approaches, such as LSTMs, sometimes achieved good accuracy, their performance was inconsistent across forecast horizons, reinforcing the value of models like SARIMA [10]. Data quality issues, including missing values and inconsistencies, had a significant impact on forecast reliability, requiring automated preprocessing that preserves temporal structure and continuous monitoring. In addition, shorter training windows proved more adaptive to recent load changes than longer ones, indicating that training-window length should be periodically re-optimised based on error patterns, model drift, and the impact of flexibility activations. Future improvements will include the integration of mechanisms that would allow forecasts to adapt, as flexibility increasingly changes the load profiles.

3.1.4 Flexibility Activation Mechanisms

The Greek pilot enabled the end-to-end validation of two distinct flexibility mechanisms, namely tariff-based incentives (BUC 4 – Green Charging) and capacity-based control (BUC 5 – Flexible Capacity Contracts). From a technical perspective, both approaches were successfully implemented, demonstrating the capability of the system to coordinate grid signals and EV charging behaviour in near real time.

In particular, the pilot confirmed that flexibility signals can be reliably generated at the DSS level, transmitted to the O-V2X-MP platform, and translated into actionable commands at the charging infrastructure level. These commands included dynamic tariff adjustments and charging power limitations, which were applied seamlessly during active charging sessions. Importantly, all control actions were executed without interrupting user activity, demonstrating that flexibility services can be delivered in a non-intrusive and user-friendly manner. This constitutes a significant positive outcome, confirming the technical feasibility of grid-responsive charging and the ability to combine both indirect (price-based) and direct (capacity-based) control mechanisms within a unified system architecture.

Despite this strong technical validation, the pilot also revealed important limitations regarding the practical effectiveness and real-world impact of these mechanisms. In particular, the relatively limited number of deployed charging stations and participating EV users resulted in a low overall impact on the distribution grid, with no significant congestion events or voltage violations observed during the demonstration period. As a consequence, the activation of flexibility services was primarily based on controlled or simulated triggers. While this approach enabled the verification of the end-to-end operational chain, from detection to response, it did not fully capture the complexity of real operational environments, where higher penetration levels would lead to stronger interactions between grid conditions, user behaviour, and market signals.

Furthermore, the pilot highlighted that the effectiveness of flexibility mechanisms is strongly dependent on the strength and realism of activation signals. In the absence of significant economic incentives or operational constraints, user response to tariff-based signals remained moderate. This indicates that the success of such mechanisms depends not only on technical implementation, but also on the existence of clear and attractive value propositions for end-users and operators.

An additional key insight concerns the interaction between different flexibility approaches. While tariff-based mechanisms influence user behaviour indirectly, capacity-based mechanisms allow direct enforcement of grid constraints. Although both approaches proved technically viable, their combined application in real systems requires careful coordination, as overlapping signals or conflicting objectives may arise between stakeholders. This highlights the need for integrated control strategies and well-defined prioritisation logic.

The pilot also provided important lessons regarding user interaction and engagement. While real-time notification capabilities were successfully implemented, it became evident that broad, non-targeted communication strategies are neither efficient nor user-friendly. Indiscriminate notifications may lead to information overload and reduced user engagement, ultimately limiting the effectiveness of demand response actions. Instead, the pilot demonstrated the need for targeted notification mechanisms, where users are informed based on contextual relevance, such as proximity to the affected charging location, frequency of use, user preferences, or historical behaviour. This approach enhances the effectiveness of communication while preserving user acceptance, highlighting that user engagement is as much a communication challenge as it is a technical one.

Another important lesson relates to the allocation of charging power under grid constraints. In the pilot, capacity limitations were implemented using a horizontal allocation approach, whereby available power was equally distributed among connected vehicles. While this method ensures simplicity and basic fairness, it does not optimise system performance or user satisfaction, as it does not account for parameters such as battery state of charge, required energy, or expected connection duration. More advanced allocation strategies, based on prioritisation or optimisation, could significantly improve outcomes, but require additional data, more complex algorithms, and potentially increased user interaction. This introduces a fundamental trade-off between system optimisation and user convenience, which must be carefully addressed in future implementations.

Finally, the limited activation of flexibility services under real conditions is closely linked to the current regulatory and market context. In the Greek case, the absence of established frameworks for flexibility procurement at the distribution level, as well as the lack of mature mechanisms for dynamic network tariffs and remuneration, meant that flexibility signals were largely experimental. This highlights that, despite technical readiness, the absence of enabling regulatory and market structures remains a key barrier to large-scale deployment.

Lessons learned: The pilot demonstrates that flexibility activation mechanisms are technically mature and operationally feasible, with proven capability to integrate forecasting, decision-making, and real-time control. However, their full value can only be realised when deployed in environments where grid needs, user engagement, and market incentives are aligned. The key lesson is that flexibility services must be understood as socio-technical solutions, whose effectiveness depends on the coordinated development of technology, regulation, and market design.

3.1.5 Interoperability and Communication Standards

The adoption of open communication standards, and in particular the OCPP, played a key role in enabling the integration between the charging infrastructure and the central management platform. This facilitated real-time monitoring, control of charging sessions, and the implementation of smart charging functionalities, confirming the importance of standardised protocols as a foundation for system interoperability and scalability.

At the same time, the pilot highlighted that the existence of standards does not automatically ensure seamless interoperability in practice. Differences in implementation across manufacturers, variations in supported features, and vendor-specific adaptations resulted in additional integration effort and the need for system-level adjustments. In particular, while OCPP 2.0.1 introduces enhanced capabilities, such as improved smart charging, device management, and support for advanced services, its adoption in commercially available charging infrastructure remains limited and inconsistent. As a result, many deployments still rely on OCPP 1.6 or partial implementations of newer versions, restricting the full utilisation of advanced functionalities.

Furthermore, OCPP 2.0.1 can be considered a transitional step towards OCPP 2.1, which aims to further align with emerging requirements, including improved support for ISO 15118-based communication and bidirectional charging. This indicates that the ecosystem is still evolving, with standards and implementations progressing in parallel.

Beyond the charger–platform interface, the pilot also highlighted the absence of widely adopted and harmonised standards for communication between DSO and CPO. While several approaches and protocols exist (e.g., OpenADR, IEC 61850, or project-specific APIs), there is currently no universally accepted framework for exchanging flexibility signals and coordinating grid-driven services. As a result, integration often relies on customised solutions, which limit interoperability and scalability.

Lessons learned: The key lesson is that while standardisation is a critical enabler for smart charging ecosystems, it remains in a transitional phase, particularly for advanced services such as V2G and ISO 15118-based communication. Achieving true interoperability will require not only the definition of standards, but also their consistent and widespread implementation across the value chain, as well as further harmonisation of interfaces between grid operators and mobility service providers.

3.1.6 V2G Technology Readiness

One of the most critical insights from the Greek pilot concerns the current maturity level of Vehicle-to-Grid (V2G) technologies and their readiness for real-world deployment. Although V2G-capable charging equipment was installed and technically operational within the pilot, bidirectional operation was not realised under actual conditions.

This limitation is primarily attributed to the low maturity of the V2G ecosystem in the Greek market, both on the infrastructure and vehicle sides. On the infrastructure side, while V2G-enabled EVSEs are commercially available, their deployment remains limited in scope, and their advanced functionalities (e.g., OCPP 2.0.1 support, ISO 15118 communication) are not yet fully implemented or activated in practice. On the vehicle side, the availability of V2G-compatible EVs is extremely restricted, with only a small number of models supporting bidirectional charging, often based on proprietary standards (e.g., CHAdeMO), which further limits interoperability and scalability.

In addition, the absence of fully standardised and widely adopted communication protocols for bidirectional operation, combined with the lack of certification procedures and interoperability testing frameworks, further constrains deployment. These technical limitations are compounded by regulatory and market barriers, including the absence of clear rules for energy injection into the grid, a lack of remuneration schemes for V2G services, and uncertainty regarding the roles and responsibilities of involved stakeholders.

Taken together, these factors highlight a significant gap between component-level readiness and system-level deployment. While individual technologies (chargers, vehicles, and communication protocols) exist and have been validated in controlled or pilot environments, their integration into a coherent, interoperable, and scalable ecosystem remains limited.

At the same time, simulation results from the pilot clearly demonstrate the high potential of V2G services, indicating significant benefits in terms of flexibility provision, peak load reduction, cost optimisation, and emissions reduction. This confirms that V2G represents a high-impact solution for future energy systems, particularly in scenarios with high EV penetration and renewable energy integration.

Lessons learned: V2G should be considered a promising but not yet mature solution, requiring further development and alignment across multiple dimensions. These include:

- wider availability of V2G-compatible vehicles,
- maturation and harmonisation of communication standards (e.g., ISO 15118),
- improved implementation of advanced protocols (OCPP 2.x),
- and, critically, the establishment of supportive regulatory and market frameworks.

In its current state, the Greek market can be characterised as being in an early adoption phase for V2G, where technological capabilities are emerging, but the necessary ecosystem for large-scale deployment is not yet in place.

3.1.7 System Architecture and Scalability

The architecture of the O-V2X-MP platform, based on a modular and microservices-oriented design, proved to be a key enabler for system integration, flexibility, and future extensibility. This architectural approach allows individual components to be developed, deployed, and updated independently, facilitating the integration of heterogeneous systems such as charging infrastructure, grid monitoring tools, and external services. It also supports the gradual addition of new functionalities, including advanced smart charging schemes, forecasting modules, and potential V2G services, making it well suited for evolving operational requirements.

From a technical perspective, the pilot confirmed that such an architecture can effectively support real-time communication, data exchange, and control actions across multiple system layers. The separation of functionalities into distinct services contributed to system robustness and maintainability, while the use of APIs enabled interoperability with external platforms and stakeholders.

However, the pilot was conducted at a relatively limited scale, involving a small number of charging stations and users. As a result, the scalability of the system was only partially validated. While performance under pilot conditions was stable, the transition to large-scale deployment introduces additional challenges that were not fully tested within the scope of the demonstration.

A particularly important limitation relates to the interaction between the DSO and CPOs. In the pilot, the interaction model was effectively one-to-one, involving a single DSO and a single CPO. Under these conditions, the coordination of flexibility signals and capacity constraints was straightforward, as all charging infrastructure was managed within a single operational framework.

In real-world deployments, however, a single DSO is expected to interact with multiple CPOs operating within the same geographical area. This raises critical questions regarding:

- how available grid capacity should be allocated among different CPOs,
- how fairness and transparency can be ensured across competing actors,
- and how coordination mechanisms can prevent conflicting or inefficient control actions.

Without a well-defined allocation mechanism, there is a risk that capacity constraints may be applied unevenly or inefficiently, potentially leading to:

- suboptimal utilisation of available flexibility,
- unfair treatment of different service providers,
- and reduced overall system efficiency.

Addressing this challenge requires the development of coordination and market-based mechanisms capable of distributing available capacity among multiple actors. Possible approaches may include:

- proportional allocation schemes,
- priority-based access,
- or market-driven mechanisms (e.g., local flexibility markets or auctions).

However, such solutions introduce additional complexity in terms of system design, communication requirements, and regulatory oversight.

In addition to multi-actor coordination, future large-scale deployments will need to address:

- significantly increased data volumes generated by real-time monitoring, forecasting, and user interactions,
- a much higher number of connected devices (e.g., chargers, meters, and EVs),
- and more complex coordination requirements across multiple actors, locations, and grid constraints.

These factors may impact system performance in terms of latency, reliability, and data processing, requiring enhanced infrastructure, distributed computing capabilities, and advanced orchestration mechanisms. Furthermore, scalability will also depend on robust cybersecurity measures, efficient data management, and fault-tolerant system design.

Overall, the pilot demonstrates that the adopted system architecture provides a solid and flexible foundation for smart charging and flexibility services. However, scaling such systems to real-world conditions will require not only technical enhancements but also the development of multi-actor coordination frameworks, particularly at the interface between DSOs and multiple CPOs.

Lessons learned: Scalability is not solely a technical challenge, but also a system-level coordination problem, where architecture, market design, and governance mechanisms must evolve together to enable efficient and fair operation.

3.2 Market and Regulatory Lessons

This subsection presents the key market and regulatory insights derived from the Greek pilot, focusing on the conditions required for the effective deployment of smart charging and flexibility services. While the pilot successfully demonstrated the technical feasibility and operational functionality of the proposed solutions, it also revealed that market structures and regulatory frameworks remain a critical limiting factor for large-scale implementation.

3.2.1 Absence of Mature Flexibility Markets at Distribution Level

A central finding of the pilot is the absence of mature and operational flexibility markets at the distribution level in Greece. Although the system demonstrated the capability to activate flexibility services through both tariff-based and capacity-based mechanisms, these activations were not supported by real market processes. Instead, flexibility signals were applied within an experimental framework, without formal procurement mechanisms, contractual obligations, or remuneration schemes. This significantly limits the ability to assess the economic sustainability of such services and highlights the lack of structured environments where DSOs can request, procure, and remunerate flexibility in a transparent and competitive manner.

In this context, the pilot indicates that dynamic capacity connection contracts could represent a practical and realistic first step towards the introduction of flexibility-based grid management. Such schemes would allow DSOs to define dynamic limits on connection capacity, enabling controlled access to the grid based on real-time conditions, while providing a clear contractual framework between DSOs and CPOs. Compared to fully developed flexibility markets, dynamic connection contracts are simpler to implement, require fewer regulatory changes, and can be integrated within existing grid operation practices. As such, they can act as a transitional mechanism, facilitating the gradual introduction of active demand management and grid-responsive charging.

However, while dynamic capacity allocation mechanisms can support initial deployment, they do not fully exploit the potential of distributed flexibility resources, particularly in scenarios involving multiple actors and competing uses of grid capacity. Moving beyond this initial stage requires the development of more advanced flexibility market schemes, where flexibility is treated as a tradable service and allocated through market-based mechanisms. Such schemes would enable efficient price discovery, fair competition among service providers, and optimal allocation of resources across the network.

The transition from static or contract-based approaches to fully operational flexibility markets entails several challenges, including the definition of market roles, the establishment of standardised products, the integration with existing energy markets, and the development of appropriate regulatory oversight. The pilot highlights that, while the technical infrastructure can support such evolution, the market design and regulatory framework are not yet sufficiently mature to enable this transition.

Lessons learned: Flexibility deployment should be approached through a phased and evolutionary pathway, starting from simpler mechanisms such as dynamic connection capacity contracts and progressively advancing towards fully developed flexibility markets. This staged approach can reduce implementation risks, allow stakeholders to adapt gradually, and create the necessary conditions for unlocking the full value of smart charging and V2G services.

3.2.2 Limitations of Current Tariff Structures

The pilot highlighted significant limitations in existing electricity tariff structures, particularly with respect to their ability to support smart charging and flexibility services. Current tariff schemes, including Distribution Use of System charges, are predominantly static and predefined, lacking the granularity and temporal resolution required to reflect real-time grid conditions.

Within the pilot, dynamic tariff signals were successfully implemented to incentivise specific charging behaviours, such as increased demand during periods of high renewable generation or reduced consumption under potential grid constraints. These signals included both positive incentives (e.g., reduced tariffs for "green charging") and restrictive signals (e.g., increased costs during congestion scenarios). However, these mechanisms were applied in a controlled, experimental context, outside the constraints of the existing regulatory framework.

In real-world conditions, tariff structures do not yet support such dynamic adjustments. Network tariffs are typically fixed over long periods and are not designed to respond to short-term variations in grid conditions. As a result, they fail to provide timely and location-specific economic signals that could effectively influence user behaviour and support grid operation. This limitation reduces the ability of smart charging systems to realise their full potential as flexibility providers.

Furthermore, the pilot revealed that the introduction of dynamic tariffs significantly increases the complexity of tariff design and implementation. Smart charging scenarios require the coordination of multiple pricing components, including wholesale energy prices, network tariffs, and flexibility incentives. The interaction between these components must be carefully managed to ensure consistency, avoid conflicting signals, and maintain economic efficiency.

This complexity extends to billing and settlement processes, which become more challenging as tariffs vary over time and across locations. Ensuring accurate calculation of charges, transparent communication to users, and alignment between different stakeholders (e.g., suppliers, DSOs, and CPOs) requires advanced data management and system integration capabilities. In addition, from a user perspective, overly complex tariff structures may reduce transparency and hinder understanding, ultimately limiting user responsiveness.

Another important aspect concerns the regulatory constraints on tariff design. In many cases, DSOs are not currently allowed to apply fully dynamic or location-specific tariffs, and existing frameworks do not support real-time tariff updates or flexibility-based pricing. This restricts the ability to implement innovative pricing schemes, even when the technical infrastructure is available.

Lessons learned: Effective deployment of smart charging services requires the evolution of tariff frameworks towards more dynamic, transparent, and grid-responsive structures, capable of reflecting real-time system conditions and providing clear and actionable economic signals to users. Such evolution must be accompanied by regulatory adaptations, improved billing mechanisms, and user-centric design to ensure both operational feasibility and user acceptance.

3.2.3 Regulatory barriers to V2G deployment

The pilot also highlighted significant regulatory barriers to the deployment of V2G services. Despite the availability of V2G-capable infrastructure, bidirectional operation could not be implemented under real conditions, primarily due to the absence of a clear and comprehensive regulatory framework governing energy injection from electric vehicles into the distribution grid.

A key challenge relates to the lack of defined roles and market participation schemes for EVs acting as distributed energy resources. In the current regulatory environment, EVs are not formally recognised as flexibility providers or prosumers capable of injecting energy back into the grid in a structured and remunerated manner. This creates uncertainty regarding who is allowed to provide such services, under what conditions, and through which market mechanisms.

In addition, several critical commercial aspects remain unresolved. These include licensing requirements for energy export, which may impose administrative burdens on individual users or service providers, as well as the absence of standardised metering and validation procedures for accurately measuring bidirectional energy flows. Without appropriate metering frameworks, it is not possible to ensure reliable settlement of energy transactions or to verify the provision of flexibility services.

Further complexity arises in relation to settlement and remuneration mechanisms. There is currently no established framework for compensating V2G services, whether through energy markets, ancillary services, or distribution-level flexibility schemes. This limits the economic viability of V2G participation and discourages both users and service providers from engaging in such activities. Moreover, taxation rules and tariff structures are not designed to accommodate bidirectional energy flows, raising concerns about double charging, unclear cost allocation, and potential regulatory inconsistencies.

The pilot also revealed the absence of clear technical and operational standards for integrating V2G into grid operation, including procedures for activation, control, and coordination with DSO systems. This lack of standardisation further complicates the deployment of V2G services and increases the need for project-specific solutions.

Taken together, these regulatory and market gaps create a significant disconnect between the technical readiness of V2G technologies and their practical deployment. While the pilot and simulation results demonstrate the strong potential of V2G to provide flexibility, reduce peak demand, and support renewable integration, these benefits cannot be realised without a supportive regulatory environment.

Lessons learned: V2G requires a comprehensive regulatory framework that addresses the full value chain, including clear definitions of roles and responsibilities, streamlined licensing procedures, robust metering and settlement systems, appropriate tariff and taxation rules, and access to flexibility markets. Without such alignment, V2G will remain a promising but largely unrealised capability within the energy system.

3.2.4 Maturity of V2G market in Greece

The Greek pilot highlighted that, despite the growing adoption of electric mobility, the maturity of the e-mobility ecosystem in Greece remains at an early stage, particularly with respect to bidirectional charging capabilities.

On the infrastructure side, the EV charging market (EVSE) has experienced steady growth in recent years, supported by national incentives and increasing interest from both public and private stakeholders. A variety of AC and DC charging solutions are commercially available and widely deployed, primarily supporting unidirectional charging based on established standards such as Type 2 (AC) and CCS (DC). However, when focusing specifically on V2G-ready charging infrastructure, the market remains limited in scope. While a small number of V2G-capable chargers are commercially available internationally, their presence in the Greek market is minimal and largely restricted to pilot projects and demonstration activities. In addition, many of these systems rely on proprietary or less widely adopted technologies, such as CHAdeMO-based bidirectional charging, which further constrains interoperability and long-term scalability.

From a technological perspective, newer standards such as ISO 15118, which enable advanced functionalities including plug-and-charge and bidirectional communication, are still in the early stages of deployment. Similarly, although OCPP 2.0.1 introduces support for more advanced smart charging and V2G functionalities, its implementation across commercially available EVSEs remains partial. As a result, even where hardware capabilities exist, full activation of V2G services is often not feasible in practice.

On the vehicle side, the availability of V2G-compatible EVs is even more constrained. Only a limited number of vehicle models globally support bidirectional charging, and these are typically based on CHAdeMO technology, which is gradually being phased out in favour of CCS in the European market. Vehicles supporting V2G through CCS and ISO 15118-20 are only beginning to emerge and are not yet widely available commercially. Consequently, the Greek EV fleet currently consists almost entirely of unidirectional charging vehicles, with negligible penetration of V2G-capable models.

This situation creates a fundamental limitation for the deployment of V2G services, as both sides of the ecosystem, EVSE and EV, must be simultaneously capable and interoperable. The pilot clearly demonstrated that the absence of either component prevents real-world implementation, regardless of the readiness of the other.

In addition to technological constraints, market maturity is further affected by the lack of standardised certification procedures, interoperability testing frameworks, and large-scale commercial offerings for V2G solutions. This results in a fragmented landscape where available products are not always compatible or ready for integration into broader systems.

Overall, the Greek market can be characterised as being in an early adoption phase for V2G, where:

- EV charging infrastructure is expanding but remains focused on unidirectional operation,
- V2G-capable chargers are available but not widely deployed or fully operational,
- and V2G-compatible vehicles are scarce and not aligned with the dominant European charging standards.

Lessons learned: While V2G technology is progressing at the global level, its market readiness in Greece is still limited, requiring further development of both EV and EVSE offerings, alignment with emerging standards (e.g., CCS and ISO 15118), and increased commercial availability of interoperable solutions. Without such evolution, V2G deployment will remain confined to pilot environments and will not scale to real-world applications.

3.3 Social acceptance and readiness level

This subsection summarises the findings from the user survey conducted during the Greek pilot, aiming to assess user satisfaction, behavioural response, and overall readiness for smart charging and flexibility services. Although the survey sample was relatively limited, it provides valuable qualitative insights into user perception and acceptance of the deployed solutions.

Overall, the results indicate a high level of user satisfaction and positive acceptance of the charging infrastructure and associated digital platform. Users reported a generally smooth and reliable charging experience, confirming that the system meets basic expectations in terms of usability, accessibility, and performance. The absence of disruptions during charging sessions and the intuitive interaction with the platform contributed significantly to this positive perception.

At the same time, the survey results suggest that user engagement with advanced smart charging functionalities remains moderate. While users were receptive to the concept of dynamic pricing and flexibility services, their actual interaction with such features was limited. This can be attributed to several factors, including the relatively low frequency of activated signals, the limited variability of tariffs, and the absence of strong economic incentives during the pilot period.

A key finding concerns user awareness and understanding of flexibility services. Although users generally expressed openness to participating in smart charging schemes, their level of understanding of concepts such as dynamic tariffs, grid constraints, or V2G services was not always sufficient to support active engagement. This highlights the importance of clear communication and user education, particularly when introducing more complex energy services.

The survey also indicates that non-intrusive operation is a critical factor for user acceptance. Users showed a clear preference for solutions that do not interfere with their charging routines or require active intervention. Flexibility mechanisms that operate transparently in the background, without disrupting the charging process, are more likely to be accepted than those requiring manual input or behavioural change.

Another important insight relates to trust and transparency. Users are more willing to participate in smart charging schemes when they:

- clearly understand the benefits,
- can access transparent information on pricing and charging behaviour,
- and trust that the system operates reliably and fairly.

Lack of transparency or overly complex tariff structures may reduce user confidence and limit participation.

Finally, the limited size and composition of the user group should be considered when interpreting the results. Participants in pilot projects are often more engaged and open to innovation than the general population, which may lead to more positive feedback compared to large-scale deployment scenarios.

Lessons Learned: The survey results lead to several important conclusions regarding social acceptance and readiness:

- Users show high acceptance of EV charging infrastructure and digital platforms, confirming readiness for wider deployment.
- Acceptance of smart charging depends strongly on non-intrusive and user-friendly operation.
- Economic incentives are necessary to drive active participation in flexibility services.
- User awareness and understanding remain limited, requiring improved communication and education.
- Trust, transparency, and simplicity are key enablers of user engagement.

4 Business Model Assessment

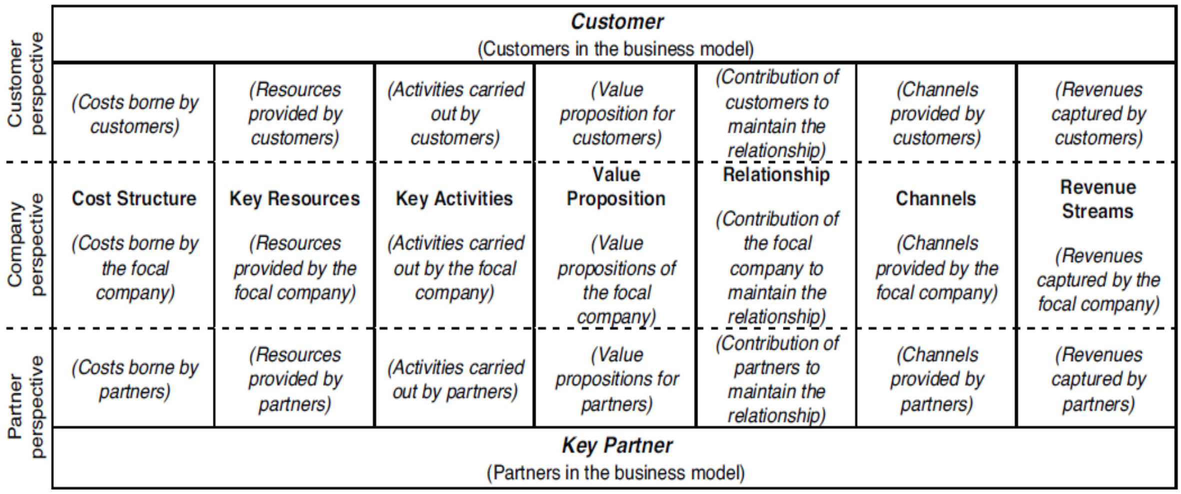
4.1 Assessment approach - Service Business Model Canvas

The Service Business Model Canvas (SBMC), illustrated in Figure 7, is adopted as the methodological framework for analysing and structuring the business models of the developed services. The SBMC extends the traditional Business Model Canvas by explicitly incorporating a multi-actor perspective, distinguishing between customer, company, and partner roles within the ecosystem. This is particularly relevant for smart charging and V2G flexibility services, which are inherently service-oriented and involve complex interactions among multiple stakeholders.

The SBMC is applied in a systematic manner to capture the key elements of each actor’s involvement in the service. For each perspective, the analysis covers the cost structure, key resources, key activities, value proposition, relationship mechanisms, communication channels, and revenue streams. This structured approach enables a comprehensive mapping of how value is created, delivered, and captured across the ecosystem, while also highlighting the interdependencies between actors.

The methodology supports the identification of value co-creation mechanisms, as well as the allocation of costs, benefits, and responsibilities among stakeholders. In addition, it provides a consistent framework for comparing different use cases and assessing their scalability and economic viability. The SBMC development in this study is informed by the results of the demonstration activities, including KPI evaluation, expert knowledge from pilot implementation, and the lessons learned derived from technical, operational, and market analyses.

By applying the SBMC as a methodological tool, the study is able to bridge the gap between technical validation and business model development, providing a holistic understanding of the conditions required for the deployment of smart charging and V2G services.



	Customer (Customers in the business model)						
Customer perspective	*(Costs borne by customers)*	*(Resources provided by customers)*	*(Activities carried out by customers)*	*(Value proposition for customers)*	*(Contribution of customers to maintain the relationship)*	*(Channels provided by customers)*	*(Revenues captured by customers)*
Company perspective	**Cost Structure** *(Costs borne by the focal company)*	**Key Resources** *(Resources provided by the focal company)*	**Key Activities** *(Activities carried out by the focal company)*	**Value Proposition** *(Value propositions of the focal company)*	**Relationship** *(Contribution of the focal company to maintain the relationship)*	**Channels** *(Channels provided by the focal company)*	**Revenue Streams** *(Revenues captured by the focal company)*
Partner perspective	*(Costs borne by partners)*	*(Resources provided by partners)*	*(Activities carried out by partners)*	*(Value propositions for partners)*	*(Contribution of partners to maintain the relationship)*	*(Channels provided by partners)*	*(Revenues captured by partners)*
	Key Partner (Partners in the business model)						

Figure 7 Service Business Model Canvas Template

4.2 SBMC for Green Charging Service

The SBMC in Table 1 provides a structured representation of the Green Charging service, highlighting how value is created, delivered, and captured across the involved actors.

At the core of the model lies the DSO, which assumes the role of system orchestrator. Through the use of advanced monitoring and forecasting tools, the DSO identifies grid conditions, such as periods of high renewable energy generation that may lead to overvoltage issues, and translates them into actionable flexibility signals. These signals, primarily implemented in the form of dynamic DUoS tariffs and operational constraints, aim to influence EV charging behaviour in a way that supports grid stability and enhances renewable energy utilisation. The value for the DSO is primarily derived from improved grid operation, including congestion mitigation, increased hosting capacity for distributed energy resources, and the deferral of costly infrastructure upgrades.

The EV user, as the customer in this model, participates in the service by adapting charging behaviour in response to price signals. The value proposition for the user is centred on economic benefits, such as reduced charging costs during incentivised periods, as well as environmental benefits associated with increased use of renewable energy. Importantly, the pilot demonstrated that participation can be largely non-intrusive, with users engaging through familiar digital interfaces without significant disruption to their charging routines. However, the effectiveness of this interaction depends on clear communication, transparency, and the strength of the incentives provided.

The CPO and the e-mobility Service Provider play a critical intermediary role in enabling the service. The CPO manages the physical charging infrastructure and ensures the implementation of pricing signals and operational constraints at the station level, while the eMSP—through the O-V2X-MP platform—facilitates communication between the DSO and end users. This includes translating grid signals into user-facing information, managing charging sessions, and providing real-time feedback. These actors capture value through increased infrastructure utilisation, enhanced service offerings, and future participation in flexibility markets, although such revenue streams remain limited under current regulatory conditions.

The EV and EVSE manufacturers contribute indirectly by enabling vehicle and charging infrastructure compatibility with smart charging functionalities. Through the integration of communication protocols and advanced charging capabilities, manufacturers provide the technology enablers to realise the green charging service.

A key characteristic of the presented business model is the strong reliance on data exchange and digital platforms. The end-to-end process, from grid monitoring to user response, is enabled by continuous data flows between the DSS, the O-V2X-MP platform, the charging infrastructure and the user. This highlights that Green Charging is not merely an infrastructure-based service, but a digital energy service, where information plays a central role in value creation.

Despite the successful technical validation of this model, the analysis also reveals important limitations. In particular, the absence of mature flexibility markets and dynamic tariff frameworks constrains the ability to establish clear and sustainable revenue streams for all actors. Thus, its large-scale deployment depends on the evolution of regulatory frameworks, market mechanisms, and interoperability standards, which are necessary to fully unlock the economic value of flexibility services.

Table 1 Service Business Model Canvas – Green Charging

Perspective	Cost Structure	Key Resources	Key Activities	Value Proposition	Relationship	Channels	Revenue Streams
Customer (EV User)	- Charging cost (energy + DUoS tariffs) - Opportunity cost from shifting charging time	- EV and battery capacity - Access to smart chargers - Mobile app (O-V2X-MP / eMSP)	- Charging based on tariff signals - Responding to dynamic pricing - Monitoring tariffs and sessions via app	- Reduced charging cost (discounted or negative DUoS tariffs) - Access to renewable-based charging ("green charging") - Non-intrusive participation in flexibility schemes	- Interaction via app/platform - Participation in flexibility services - Trust in transparent pricing signals	- Mobile apps (eMSP / O-V2X-MP) - Charger interface - Notification system)	- Cost savings – Potential future incentives for flexibility participation
Company (DSO – HEDNO)	- Deployment of LV monitoring infrastructure - DSS development & operation – Forecasting tools integration – Communication interface with CPO/eMSP – Flexibility activation management	- DSS platform (forecasting + decision engine) - LV monitoring system (substations, feeders) - Grid data (voltage, load, RES generation) - Communication interface (DSS → O-V2X-MP)	- Detection of overvoltage risks (via forecasting) - Identification of critical substations - Generation of flexibility signals (DUoS tariffs, V2G limits) - Sending signals to O-V2X-MP - Monitoring grid response	- Voltage control and congestion mitigation - Increased RES hosting capacity - Avoided grid reinforcement investments - Improved grid observability and control	- Contractual/ operational relationship with CPO - Data exchange with platform (O-V2X-MP) - Indirect interaction with EV users via signals	- DSS platform - APIs / messaging to O-V2X-MP - Internal grid systems - LV monitoring infrastructure	- Avoided CAPEX (grid reinforcement) - Reduced operational costs - Future regulated flexibility revenues
Partner (CPO – PPC)	- V2G/Smart Charging infrastructure investment - Backend system operation upgrade (V2X interface – Maintenance & operations	- Charging stations (Type 2 AC, smart chargers) - Backend system (OCPP-based) - Customer base	- Implementation of tariff updates - Execution of charging constraints (if needed) - Standardised communication interfaces	- Grid-compliant charging network development - Reduced grid connection costs - Participation in smart charging services - Enhanced service offering	- Receives signals from DSO via platform - Applies pricing and constraints - Interface between grid and users	- Charging stations - Backend systems - OCPP communication - Platform integration (O-V2X-MP)	- Charging fees - Future flexibility remuneration

Perspective	Cost Structure	Key Resources	Key Activities	Value Proposition	Relationship	Channels	Revenue Streams
Partner (eMSP / Platform – O-V2X-MP)	- Platform development and maintenance - Data management and analytics - Integration with DSS and CPO systems	- O-V2X-MP platform - User data and profiles - Communication infrastructure (WebSocket/API)	- Real-time monitoring of charging sessions - Receiving signals from DSS - Translating signals into tariffs and constraints - Communicating with users - Managing sessions and data flows	- Real-time information to users - Smart charging interface - Enhanced user experience	- Central coordination role - Communication with both DSO and users - User engagement and notification management	- Mobile app / web interface - APIs (DSS ↔ platform ↔ CPO) - Real-time notifications	- Platform service revenues - Data-driven services - Future flexibility service fees
Partner (OEM – Vehicle Manufacturer)	- Development of EV smart charging capabilities - Integration of communication protocols (ISO 15118 readiness, OCPP2.1) - R&D costs	- EV battery systems - Onboard communication systems - Charging interface (Type 2 / CCS)	- Enabling smart charging compatibility - Supporting future V2G readiness - Data exchange with charging systems	- Enhanced vehicle value - Compatibility with smart/grid services - Future V2G readiness	- Indirect relationship via vehicle use - Integration with charging ecosystem	- Vehicle interface - Embedded communication systems	- Increased product value - Increased Competitiveness/Sales

4.3 SBMC for Flexible Capacity Contracts Service

The SBMC presented in Table 2 provides a structured representation of the Flexible Capacity Contracts service, capturing how value is created, delivered, and distributed among the involved actors. In contrast to the Green Charging use case, this model reflects a control-oriented flexibility approach, where the DSO directly manages grid constraints through contractual arrangements with CPOs.

Within this framework, the DSO assumes the central role of system operator and decision-maker. By leveraging advanced monitoring infrastructure and forecasting tools, the DSO is able to detect congestion events and capacity limitations at the distribution network level. Based on these insights, the DSO activates pre-defined contractual agreements with CPOs, imposing charging power limits and, where applicable, adjusting network tariffs. The value generated for the DSO lies primarily in enhanced grid reliability, improved utilisation of existing infrastructure, and the avoidance or deferral of costly grid reinforcement investments. This represents a shift from reactive grid management to a more proactive and optimised operation of the distribution network.

In this business model, the CPO acts as the primary customer, as it enters into contractual agreements with the DSO to provide flexibility services. The CPO is responsible for implementing the required charging constraints at the infrastructure level, adjusting tariffs, and managing user interactions under constrained conditions. While this introduces additional operational complexity and potential revenue limitations due to reduced charging capacity, it also provides strategic advantages. These include guaranteed access to the grid, participation in future flexibility markets, and increased competitiveness through the provision of grid-compliant charging services. The value proposition for the CPO is therefore based on both operational continuity and long-term positioning within an evolving flexibility-driven energy market.

The eMSP, through the O-V2X-MP platform, plays a critical intermediary role in enabling the service. It ensures the seamless translation of DSO signals into operational commands and user-facing information, while managing communication between the DSO, CPO, and end users. The platform acts as a coordination layer, supporting real-time data exchange, system visibility, and user engagement. Its value lies in facilitating the integration of multiple actors and ensuring the smooth operation of the service.

The EV user remains a key participant affected by the service. Users experience charging constraints in the form of reduced power or higher tariffs during congestion periods. However, the service ensures continued access to charging infrastructure under constrained grid conditions, preventing more severe disruptions.

Manufacturers contribute by enabling the technical capabilities required for controlled and bidirectional charging. Through the integration of advanced communication protocols and battery management systems, manufacturers support the evolution of vehicles and charging infrastructures into active grid participants, although their role in the current implementation remains largely enabling rather than operational.

A defining characteristic of this business model is its strong reliance on contractual relationships and direct control mechanisms, as opposed to behavioural incentives. The service is built on formal agreements between DSOs and CPOs, supported by continuous data exchange through digital platforms. This highlights the importance of interoperability, real-time communication, and system coordination in delivering flexibility services.

Despite its technical feasibility, the model also reveals key limitations. In particular, the absence of mature regulatory frameworks and flexibility markets limits the establishment of clear and sustainable revenue streams, especially for CPOs. Furthermore, the scaling of such services introduces additional challenges related to coordination among multiple actors, fair allocation of available capacity, and the need for transparent and standardised contractual arrangements.

Table 2 Service Business Model Canvas – Flexibility Capacity Contracts Service

Perspective	Cost Structure	Key Resources	Key Activities	Value Proposition	Relationship	Channels	Revenue Streams
Customer (CPO)	- System adaptation costs (backend upgrades) - Integration with DSO/platform - Operational complexity	- Charging infrastructure (EVSE network) - Backend systems (OCPP-based) - EV user participation	- Implementing power limitations - Adjusting tariffs (based on DSO signals) - Managing charging sessions under constraints - Communicating changes to users	- Guaranteed grid access under constraints - Participation in flexibility schemes - Potential compensation for flexibility provision - Avoidance of stricter grid connection limits	- Contractual agreement with DSO - Data exchange on flexibility activation - Compliance with grid constraints	- Backend systems - OCPP communication - Platform integration (O-V2X-MP)	- Flexibility remuneration (future) - Increased competitiveness
Company (DSO – HEDNO)	- DSS development and operation - LV monitoring infrastructure - Forecasting and congestion detection tools - Communication interfaces	- DSS platform (real-time monitoring & control) - Grid data (load, voltage, forecasts) - Contracts with CPOs - Communication interfaces	- Identification of congestion events - Activation of capacity constraints - Sending control signals (power limits, network tariffs) - Monitoring compliance and grid response - Managing contracts with CPOs	- Direct congestion management - Improved grid reliability - Optimised network utilisation - Avoided or deferred grid investments	- Contract-based relationship with CPOs - Operational coordination - Data exchange for flexibility activation	- DSS platform - APIs / messaging systems - Internal grid systems - Monitoring infrastructure	- Avoided CAPEX (grid reinforcement) - Improved operational efficiency
Partner (eMSP / Platform – O-V2X-MP)	- Platform development and maintenance - Integration with DSS and CPO systems - Data management costs	- O-V2X-MP platform - Communication infrastructure (API/WebSocket) - User interface tools	- Translating DSO signals into charging constraints - Communicating with CPO and users - Managing sessions under constraints - Providing real-time updates	- Real-time coordination layer - Enhanced system visibility - User communication and experience management	- Central intermediary between DSO and CPO/users - Enables system-wide coordination	- Mobile apps / web platforms - APIs (DSS ↔ platform ↔ CPO) - Notification systems	- Platform service revenues - Data-driven services - Future flexibility coordination fees

Perspective	Cost Structure	Key Resources	Key Activities	Value Proposition	Relationship	Channels	Revenue Streams
Partner (EV User)	- Higher charging cost during congestion - Reduced charging power - Potential inconvenience	- EV and battery - Access to charging services	- Charging under constraints - Adapting behaviour (if possible)	- Guaranteed access to grid (even under constraints) - Avoidance of service interruption - Transparency of grid conditions	- Interaction via app/platform - Indirect participation in flexibility	- Mobile apps - Charging stations - Notifications	- Service enabler - Increased competitiveness
Partner (OEM – Vehicle Manufacturer)	- R&D costs for smart charging - Power electronics for bidirectional inverters in AC mode - Integration of communication protocols	- EV systems and communication interfaces - Battery management systems	- Supporting controlled charging - Enabling future advanced flexibility features	- Compatibility with grid services - Improved vehicle functionality	- Indirect ecosystem integration	- Vehicle interface - Embedded systems	- Increased product value - Competitive differentiation

5 Marketability guidelines

5.1 Deployment framework for V2G services

The successful market uptake of V2G services depends not only on the availability of enabling technologies but also on the effective alignment of infrastructure capabilities, interoperability standards, regulatory frameworks, and market mechanisms. Building on the lessons learned from the Greek demonstrator, as well as the supporting technical analysis, this section outlines key guidelines to support the scalable deployment of V2G services, addressing both technical readiness and market and regulatory conditions.

V2G should be understood as a system-level innovation, in which electric vehicles operate as distributed energy resources that interact dynamically with the electricity grid. While the pilot demonstrated that individual technological components, such as charging infrastructure, digital platforms, and communication protocols, are already available, it also highlighted that their integration into a coherent, fully operational ecosystem remains limited.

Within the PPC context, the deployment of V2G services is based on a multi-layered architecture comprising electric vehicles, charging infrastructure, backend systems, and grid operators. In this architecture, the O-V2X-MP platform plays a central coordination role, enabling the translation of grid signals into charging and discharging actions, while facilitating real-time communication and data exchange among stakeholders.

Despite this progress, the pilot results indicate that V2G deployment is still at an early stage of adoption. Significant gaps remain between technical capability and real-world implementation, highlighting the need for further alignment across technological development, regulatory frameworks, and market structures to enable large-scale deployment.

5.1.1 Technical Requirements for Deployment

The deployment of V2G services requires a comprehensive set of technical capabilities across all system layers, ensuring interoperability, control, security, and scalability.

- **Bidirectional Charging Capability**

At the core of V2G deployment lies the ability to support bidirectional power flows, allowing EVs to both consume and inject energy into the grid. This requires:

- bidirectional EVSEs (AC or DC),
- EV compatibility with V2G functionality, and
- stable switching between charging and discharging modes.

Such functionality must be supported through advanced communication standards, particularly ISO 15118-20, which enables dynamic negotiation of charging or discharging schedules and grid parameter exchange.

- **Communication and Interoperability Framework**

Interoperability is a critical enabler for large-scale V2G deployment. Systems must rely on open, standardised protocols across all interfaces:

- EV ↔ EVSE: ISO 15118-20 (bidirectional communication, Plug & Charge),
- EVSE ↔ Backend: OCPP 2.0.1 / OCPP 2.1 (advanced smart charging and V2G control), and
- Backend ↔ Market actors: OCPI (data exchange, roaming, and flexibility services).

These protocols ensure seamless interaction between actors and enable real-time control and coordination. However, current implementations reveal incomplete adoption and limited interoperability, particularly for V2G-specific functionalities.

- **Backend and Platform Upgrade**

The deployment of V2G services requires the enhancement of existing EVSE management platforms to support bidirectional operation and advanced grid interaction capabilities. Rather than relying on entirely new systems, a key requirement is the upgrade of current charging management platforms (e.g., O-V2X-MP) to incorporate V2G functionalities.

In this context, the platform must evolve into a central orchestration layer capable of:

- translating grid signals into executable charging and discharging commands,
- managing both charging and bidirectional energy flows at the session level,
- enabling real-time monitoring, control, and optimisation of charging behaviour, and
- providing user interaction mechanisms, including feedback and transparency on system conditions.

- **Smart Metering and Data Management**

V2G deployment requires advanced metering capabilities beyond conventional smart charging:

- measurement of both imported and exported energy,
- high temporal resolution data, and
- certified metering (MID compliance).

These capabilities are essential for accurate billing, settlement, and market participation. In the Greek context, current metering infrastructure remains largely unidirectional, highlighting a key deployment gap.

- **Cybersecurity and Data Protection**

Given the active role of EVs in grid operation, V2G systems must implement robust cybersecurity measures:

- end-to-end encryption (TLS),
- certificate-based authentication (PKI),
- secure communication across all interfaces, and
- compliance with IEC 62443 and NIS2 requirements.

These measures ensure secure and resilient system operation, protecting against cyber threats and unauthorised control.

- **Grid Integration and Control Capabilities**

V2G systems must support:

- exchange of grid constraints and flexibility signals,
- active/reactive power control, and
- compliance with grid codes (e.g., EN 50549).

This enables EVs to operate as grid-supporting assets, contributing to congestion management and system stability.

5.1.2 Market and Regulatory Considerations

Beyond technical readiness, the deployment of V2G services depends heavily on the evolution of market structures and regulatory frameworks.

- **Market Integration and Flexibility Participation**

V2G services require integration into electricity markets, enabling EVs to:

- participate in energy and balancing markets,
- provide ancillary services, and
- act as distributed flexibility resources.

The regulatory basis for such participation is established under **Directive (EU) 2019/944**, which recognises the role of active customers and aggregators.

- **Settlement Mechanisms for Bidirectional Energy**

A key requirement for V2G is the establishment of robust settlement models:

- **Net settlement:** simplified but limited market representation,
- **Gross settlement:** enables full market participation and accurate valuation.

Gross settlement is considered more suitable for V2G but is not yet widely implemented.

- **Regulatory Gaps and Barriers**

The pilot highlighted several regulatory limitations:

- lack of clear rules for energy injection from EVs,
- absence of remuneration schemes for V2G services, and
- uncertainty regarding roles and responsibilities.

These barriers significantly limit commercial deployment and investment incentives.

- **Interoperability and Standardisation Challenges**

Although standards exist, their **inconsistent implementation** across vendors and systems creates:

- integration complexity,
- limited scalability, and
- dependence on custom solutions.

This is particularly evident in DSO–CPO communication, where no harmonised framework currently exists.

- **Economic Viability and Business Models**

The viability of V2G services depends on:

- availability of flexibility remuneration schemes,
- clear revenue streams for CPOs and users, and
- incentives for infrastructure investment.

Currently, V2G business models remain largely experimental, relying on pilot projects rather than mature market structures.

- **Transition Pathway to Market Readiness**

Based on the pilot findings, the transition towards large-scale V2G deployment requires:

- Maturation of communication standards (ISO 15118, OCPP 2.x)
- Wider availability of V2G-enabled EVs
- Deployment of bidirectional metering infrastructure
- Establishment of regulatory frameworks for flexibility markets

Only through the combined evolution of these elements can V2G move from pilot-level validation to commercial-scale deployment.

5.2 Deployment framework for Green Charging

The Greek pilot has already demonstrated the basic operational chain required for Green Charging, including LV grid monitoring, forecasting, DSS-based signal generation, communication with the O-V2X-MP platform, dynamic tariff application, and user-facing interaction. Therefore, the deployment framework for Green Charging does not focus on proving technical feasibility, but on identifying the additional actions required to move from pilot-scale validation to wider market deployment.

5.2.1 Technical Requirements for Deployment

Since the core technical components of Green Charging have already been implemented and validated in the Greek pilot, the remaining technical requirements mainly concern scalability, automation, interoperability, robustness, and replication.

A first requirement is the standardisation of the DSO–CPO/eMSP communication process. In the pilot, the interaction between the DSS and the O-V2X-MP platform was successfully implemented, but wider deployment requires a more generic and standardised interface. The exchanged information should include the activation area, time window, tariff adjustment, grid condition triggering the signal, and any operational restrictions. This interface should be designed so that different CPOs and eMSPs can participate without requiring custom integration for each case.

A second requirement is the automation and refinement of activation logic. The pilot demonstrated forecast-based triggering, but wider deployment requires robust rules for deciding when Green Charging should be activated, how strong the incentive should be, and how long the signal should remain active. These rules should account for forecast uncertainty, actual RES availability, grid loading, voltage limits, and expected user response. Over time, activation logic should be improved using operational data from larger user groups and more diverse charging locations.

A third requirement is the integration between the DSS and the charging management platform. The communication interface must allow the transfer of flexibility signals from the DSO environment to the CPO/eMSP platform in a reliable and standardized manner. These signals should include the affected charging locations, activation time window, tariff adjustment, and any operational limits required to protect the grid. APIs or standardised message formats are therefore essential to avoid project-specific integration and support scalability.

A fourth requirement is the preparation of the system for multiple CPOs and multiple charging networks. The pilot involved a limited number of charging stations and a simplified actor structure. Large-scale deployment will require mechanisms for managing Green Charging signals across different CPO backends, charger types, and user interfaces. This includes harmonised data models, common terminology, and consistent presentation of tariff signals to users.

5.2.2 Market and Regulatory Considerations

For Green Charging, the main market and regulatory gap is not technical feasibility but the absence of a framework that allows dynamic, location-specific incentives to be applied and monetised in real operation.

A key regulatory consideration is the need for dynamic and grid-responsive tariff structures. Current electricity and network tariff frameworks are generally static and do not reflect local grid conditions in real time. For Green Charging to become commercially viable, DSOs or other authorised actors must be able to issue time- and location-specific price signals that reward EV charging when it supports system operation. These signals may take the form of reduced DUoS charges, green charging discounts, flexibility incentives, or bundled tariffs offered through suppliers and eMSPs.

In addition, Green Charging should be designed to avoid social or market distortions. Dynamic incentives should not unfairly favour specific locations, user groups, or CPOs without transparent justification. As deployment scales, mechanisms may be needed to ensure fair access to incentives across different charging operators and user categories.

5.3 Deployment framework for Flexible Capacity Contracts

The Greek pilot has already demonstrated the core functionality of Flexible Capacity Contracts, including the generation of grid-related capacity limitation signals, communication from the DSS to the O-V2X-MP platform, and implementation of charging power limits at the charging infrastructure level. Therefore, the deployment framework focuses on what is still needed to transform this tested pilot mechanism into a scalable operational and contractual model.

5.3.1 Technical Requirements for Deployment

The standardisation of capacity limitation signals. For deployment beyond the pilot, the DSO should be able to communicate capacity limits to different CPO systems using a common structure. The signal should specify the affected grid area or connection point, available capacity, start and end time, reason for activation, update frequency, and required response. This would reduce dependence on custom project-specific interfaces.

The definition of fallback procedures. If communication between the DSO/DSS and CPO platform fails, the system should apply predefined safe limits or return to an agreed default mode. Similarly, if charger-level control fails, the CPO must be able to detect and report non-compliance. Such procedures are necessary to ensure grid security and maintain trust between actors.

The technical framework should be tested under higher EV penetration and real congestion scenarios. The pilot validated functionality, but the full operational value of Flexible Capacity Contracts will only become evident when the mechanism is applied in areas where EV charging creates measurable grid constraints.

5.3.2 Market and Regulatory Considerations

The main requirement for Flexible Capacity Contracts is the creation of a recognised regulatory and contractual framework for dynamic grid access. The pilot demonstrated that capacity limitation is technically feasible, but commercial deployment requires rules that define how such limitations can be applied, monetised, and governed.

A first requirement is regulatory recognition of flexible connection agreements. Current grid connection models are generally based on fixed contracted capacity. Flexible Capacity Contracts require a model in which a CPO can connect under agreed conditions that allow temporary capacity reductions. In return, the CPO may benefit from faster connection, reduced connection costs, lower network charges, or compensation for flexibility provision.

A second requirement is the definition of standard contractual terms between DSOs and CPOs. These contracts should specify the baseline capacity, flexible capacity range, activation criteria, maximum duration and frequency of limitations, notification procedures, compensation, penalties, data exchange requirements, and verification methods. This would provide certainty for both the DSO and the CPO.

A third requirement is the development of fair compensation mechanisms. Capacity limitations may reduce charging revenues, affect customer satisfaction, or increase operational complexity for CPOs. Therefore, participation should be linked to a clear economic benefit. Possible compensation models include reduced connection charges, lower fixed network fees, availability payments, activation-based payments, or future participation in distribution-level flexibility markets.

Finally, Flexible Capacity Contracts should be positioned as a practical intermediate step towards future flexibility markets. They can be implemented before fully developed local flexibility markets exist, while still creating operational experience with dynamic capacity management, DSO–CPO coordination, and flexibility valuation. In this sense, they provide a realistic pathway for scaling smart charging services under current market conditions.

6 Conclusions

This deliverable presented the analysis of the Greek pilot demonstration activities, focusing on the extraction of lessons learned and the assessment of the technical, operational, and market readiness of smart charging and V2G services. Building upon the results of Deliverable D8.5 [1], the study provided a comprehensive evaluation of system performance, stakeholder interaction, and business model development, with the aim of supporting the transition from pilot validation to real-world deployment.

From a technical perspective, the pilot successfully demonstrated the feasibility of integrated smart charging systems, including the end-to-end interaction between grid monitoring infrastructure, the DSS, the O-V2X-MP platform, and charging stations. Both flexibility mechanisms, tariff-based (Green Charging) and capacity-based (Flexible Capacity Contracts), were validated, confirming the ability to generate grid signals, communicate them across system layers, and implement them at the charging infrastructure level without disrupting user operation. These results indicate that the core technological building blocks required for smart charging and flexibility services are largely in place.

At the same time, the pilot highlighted important limitations related to system maturity and real-world impact. In particular, the relatively small scale of the deployment, in terms of charging infrastructure and EV penetration, limited the observable effects on the distribution grid. As a result, flexibility activation was mainly tested under controlled or simulated conditions, rather than through real congestion or voltage events. In addition, interoperability challenges, partial implementation of advanced communication standards (e.g., OCPP 2.x, ISO 15118), and the limited availability of V2G-compatible vehicles underline that the ecosystem is still in a transitional phase.

From an operational perspective, the pilot demonstrated that flexibility services can be implemented in a user-friendly and non-intrusive manner, particularly when relying on price-based incentives. However, it also revealed that user engagement is a critical factor, requiring targeted communication strategies and transparent value propositions. Furthermore, operational aspects such as charging power allocation under grid constraints and coordination between system actors introduce additional complexity, especially when scaling beyond pilot conditions.

The business model analysis, based on the Service Business Model Canvas, confirmed that smart charging and flexibility services are inherently multi-actor and service-oriented, relying on coordinated interactions between DSOs, CPOs, eMSPs, EV users, and technology providers. The analysis highlighted that value is primarily created through improved grid operation, increased infrastructure utilisation, and enhanced service offerings. However, it also revealed that value capture mechanisms remain underdeveloped, with limited direct revenue streams due to the absence of mature flexibility markets and regulatory frameworks.

A key finding of the study is that the main barriers to large-scale deployment are no longer purely technological. Instead, they are increasingly related to market design, regulatory conditions, and ecosystem coordination. In the Greek context, the lack of established mechanisms for flexibility procurement, dynamic network tariffs, and V2G participation creates a gap between technical capability and commercial viability. Similarly, the absence of standardised interfaces for DSO–CPO interaction and the limited maturity of V2G technologies further constrain deployment.

The marketability analysis confirmed that V2G services should be considered a system-level innovation, requiring the simultaneous evolution of infrastructure, communication standards, regulatory frameworks, and business models. While the pilot demonstrated the potential of EVs to act as flexible and grid-supporting resources, it also highlighted that their integration into real-world energy systems depends on the development of enabling conditions across multiple dimensions.

In conclusion, the Greek pilot provides strong evidence that smart charging services are technically feasible and operationally viable, while V2G services, although promising, remain at an early stage of maturity. The transition from pilot-scale validation to large-scale deployment will require:

- further standardisation and interoperability of technologies,
- increased availability of V2G-compatible vehicles and infrastructure,
- development of flexibility markets and dynamic tariff frameworks,
- and clear regulatory support enabling the participation of all actors.

Overall, the findings of this deliverable contribute to a better understanding of the conditions required for the deployment of smart charging and V2G services in Europe, supporting the transition towards more flexible, resilient, and sustainable energy systems.

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