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Executive Summary

The Slovenian demonstrator, developed within the Horizon Europe EV4EU project, provides a comprehensive validation of the role of electric vehicles (EVs) as active assets in future energy systems. It addresses a central challenge of the energy transition: integrating a rapidly growing EV fleet into electricity grids in a way that supports system stability, enables higher shares of renewable energy, and unlocks economically viable flexibility services.

Rather than treating EV charging as an additional load, the demonstrator confirms that EVs can operate as a distributed and flexible resource through Vehicle-to-Everything (V2X) technologies, aggregation via Virtual Power Plants (VPPs), and coordinated participation in electricity markets and grid services. The project successfully validated the technical feasibility and operational relevance of EV-based flexibility under real-world conditions, demonstrating its potential to support both distribution grid management and broader energy system optimisation. This validation is based on an extensive testing campaign combining real-world operation, emulation (using BESS-based EV fleet representation), and simulation-based approaches. In total, 327 test events were performed, including 72 charging tests (with an additional 195 performed under extended test conditions) and 60 discharging tests, resulting in the activation of 622.25 kWh of negative flexibility and 218.33 kWh of positive flexibility. The tests covered 1,885.7 hours of operation, with an average test duration of approximately 9 hours, demonstrating sustained and repeatable delivery of flexibility services under real and near-real operating conditions.

A key outcome of the demonstrator is the confirmation that EV-based flexibility can deliver tangible value to Distribution System Operators (DSOs). By enabling the modulation, shifting, and in some cases bidirectional use of EV charging, DSOs can mitigate local congestion, manage voltage deviations, and improve overall network reliability. These services provide a cost-efficient alternative to traditional grid reinforcement, contributing to more efficient capital allocation and long-term system planning.

From the aggregator perspective, EV integration enhances portfolio flexibility and responsiveness. EVs introduce fast-acting, distributed flexibility that complements other assets such as stationary storage and renewable generation. The demonstrator confirms that EV fleets can be effectively integrated into existing VPP architectures, although it also highlights the need to address operational uncertainty, particularly related to user behaviour and vehicle availability, through improved forecasting, aggregation strategies, and incentive design.

The project also demonstrates the importance of advanced ICT infrastructure and data-driven operation. Platforms such as VPP systems and flexibility market solutions enable coordination between DSOs, aggregators, and assets, while forecasting, monitoring, and control tools improve reliability and predictability of service delivery. High-quality, real-time data exchange and interoperability between systems are identified as critical enablers for scaling these services beyond pilot environments.

In addition, the demonstrator validates several key use cases, including EV participation in electricity markets, local flexibility markets, and grid services, as well as direct activation of flexibility by DSOs. These use cases provide a foundation for scalable business models and highlight the importance of integrating technical solutions with market mechanisms and regulatory frameworks.

Collaboration between project partners, including DSOs, aggregators, technology providers, and research institutions, emerged as a critical success factor. The project underscores that innovation in EV-based flexibility requires a coordinated, system-wide approach that combines technological development, market design, and stakeholder engagement.

Looking ahead, the transition from pilot demonstrations to large-scale deployment will depend on several key factors: improved robustness and scalability of technical solutions, stronger integration with operational processes, enhanced data access (including direct communication with EVs), and sustained user engagement. Regulatory clarity and the development of flexibility markets will also be essential to unlock the full system value of EV-based services.

Overall, the Slovenian demonstrator establishes a strong foundation for the continued development and commercialisation of EV-based flexibility solutions. It confirms that EVs can play a central role in enabling a more flexible, resilient, and decarbonised energy system, while also supporting the evolution of new market structures and business models across Europe.

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Acronyms

ADMS	Advanced Distribution Management System
aFRR	Automatic Frequency Restoration Reserve
BESS	Battery Energy Storage System
BEV	Battery Electric Vehicles
BM	Business Model
BUC	Business Use Case
CIM	Common Information Model
CPO	Charging Point Operator
CS	Charging Station
DR	Demand Response
DSO	Distribution System Operator
EMS	Energy Management Systems
ENTSO-E	European Network of Transmission System Operators for Electricity
ESS	Energy Storage Systems
EU	European Union
EV	Electric Vehicle
EVT	Unified Entry Point (slo. Enotna Vstopna Točka)
FMO	Flexibility Market Operator
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
IRL	Innovation Readiness Level
KER	Key Exploitable Result
KPI	Key Performance Indicators
LFM	Local Flexibility Market
LV	Low Voltage
mFRR	Manual Frequency Restoration Reserve
MV	Medium Voltage
PHEV	Plug in hybrid electric vehicles
PV	Photovoltaic
RES	Renewable Energy Sources
SoC	State of Charge
TRL	Technology Readiness Level
TSO	Transmission System Operator
UC	Use-Case
UL	University of Ljubljana
V1G	Smart Charging
V2G	Vehicle-to-Grid
V2X	Vehicle-to-Everything
VPP	Virtual Power Plant

1 Introduction

The electrification of transport is a central pillar of Europe's pathway towards climate neutrality, yet it poses significant challenges for electricity systems, particularly at the distribution network level. As electric vehicle (EV) adoption accelerates across EU, distribution grids are increasingly required to accommodate new and often concentrated loads while simultaneously integrating growing volumes of renewable energy sources (RES). Addressing these challenges requires more than conventional grid reinforcement; it calls for intelligent, flexible and digitally enabled solutions that allow EVs to actively contribute to system operation rather than acting solely as passive loads.

The EV4EU project was initiated to respond to this need by developing, integrating and validating advanced EV management and flexibility solutions under real operational conditions. A major outcome of EV4EU is the significant technological progress achieved during the project lifetime. The project successfully moved beyond conceptual design and simulation-based assessment towards real-world deployment and operation of EV-based flexibility solutions. Interoperable charging infrastructure, aggregation platforms, communication standards and decision-support tools for system operators were developed and tested in operational environments, resulting in several Key Exploitable Results reaching high levels of technical maturity. These achievements demonstrate that EV-based flexibility has evolved from an emerging concept into a technically viable and system-relevant solution for distribution networks.

Within this framework, Deliverable D7.4 – Lessons learned in Slovenian Demonstrator and Services Marketability report is developed under Work Package WP7 and addresses Task T7.4 (Analysis of Results) and Task T7.5 (Marketability of Proposed Solutions and Services). The main objective of this deliverable is to transform the operational experience gained during the Slovenian demonstrator into structured lessons learned and actionable insights for future deployment. While previous deliverables primarily focus on design, implementation and performance evaluation of individual solutions, this deliverable provides a qualitative synthesis aimed at supporting replication, scaling and exploitation of EV-based flexibility services.

The Slovenian demonstrator plays a particularly important role in this analysis, as it validates EV-based flexibility within a realistic market and regulatory context, including interaction with distribution system operators, aggregators and market platforms. The insights derived from this demonstrator enable a critical assessment of technological maturity, standardisation, system reliability, regulatory readiness and user behaviour.

By consolidating technical, operational and market-oriented findings, this deliverable contributes to a deeper understanding of how EV-based flexibility solutions can be transitioned from pilot environments towards broader market adoption. The lessons learned and marketability insights presented in the following chapters provide a solid foundation for future EV4EU exploitation activities and for the wider deployment of EV-based flexibility across Europe.

1.1 Scope and objectives

The analysis presented in this deliverable is grounded in the operational experience gained during the implementation of the Slovenian demonstrator within the EV4EU project. It builds on empirical evidence collected through real-world operation of EV based flexibility solutions and reflects the practical challenges and opportunities encountered during demonstration activities. This experience is complemented by the quantitative results and key performance indicators (KPIs) reported in

Deliverable D7.1 [1] and Deliverable D7.3 [2], which provide a structured assessment of technical performance, system behaviour and service effectiveness.

In addition to demonstrator data and KPI results, the analysis incorporates qualitative feedback from key stakeholders, including aggregators, Distribution System Operators (DSOs) and technology providers involved in the Slovenian demonstration. This multi-perspective input ensures that the analysis captures not only technical outcomes, but also operational, organisational and market-oriented considerations relevant for future deployment.

Lessons learned were identified through a structured review of demonstration outcomes, focusing on the identification of root causes behind observed challenges and successes, their impacts on system operation and service delivery, and potential mitigation measures. This approach allows the analysis to move beyond descriptive reporting and towards actionable insights that can inform future implementations.

Marketability was assessed by examining the value propositions of the proposed solutions, their relevance for identified target customers, the suitability of the associated business models (BMs) and revenue mechanisms, and the influence of existing regulatory and market conditions. By combining operational evidence with market and regulatory perspectives, this deliverable aims to provide a coherent and realistic assessment of the readiness of EV-based flexibility solutions for replication, scaling and exploitation.

Overall, the scope of this deliverable is to translate demonstration experience into structured knowledge that supports informed decision-making for future EV4EU exploitation activities and for the broader deployment of EV-based flexibility services in Europe.

1.2 Structure

This deliverable is structured to guide the reader from the general project context and demonstrator description towards a detailed analysis of lessons learned and an assessment of service marketability, with a clear focus on exploitation-oriented outcomes.

Following the introduction, scope and objectives, Chapter 2 provides an overview of the Slovenian demonstrator. It describes the demonstrator objectives, setup and implemented use cases, outlining the technical architecture, operational environment and stakeholder roles. This chapter establishes the practical context required for understanding the subsequent analysis and ensures transparency regarding the conditions under which the results were obtained.

Part I (Chapter 3) presents the lessons learned from the Slovenian demonstrator. The analysis is organised across multiple thematic domains, including technical aspects, operational processes, flexibility management, market and economic considerations, regulatory and institutional conditions, data and KPI-related aspects, as well as stakeholder and user perspectives. The chapter also addresses replicability and scalability, supported by cross-demonstrator comparability and knowledge transfer insights. This structured approach enables a comprehensive reflection on both enabling factors and limitations encountered during real-world deployment of EV-based flexibility solutions.

Part II (Chapter 4) focuses on the marketability assessment of the services demonstrated in Slovenia. It analyses the market context and target customers, value propositions for different stakeholder groups, business models and revenue mechanisms, market barriers and enablers. The chapter further outlines strategic market recommendations and presents future plans for innovation development, Key Exploitable Result (KER) exploitation and collaboration. In addition, the economic outlook,

development of new services, impacts on electricity prices and charging costs, and the implications for EV adoption and environmental benefits.

Finally, Chapter 5 concludes the deliverable by synthesising the main findings from both the lessons learned and marketability assessment. It highlights the overall contribution of the Slovenian demonstrator to the EV4EU project objectives and summarises the key insights relevant for future deployment and exploitation of EV-based flexibility solutions.

Through this structure, the deliverable ensures a logical progression from demonstrator implementation to analytical reflection and forward-looking conclusions, supporting replication, scaling and exploitation of the solutions developed within EV4EU.

1.3 Relationship with other deliverables

Deliverable D7.4 builds on the results of the Slovenian demonstrator and provides a synthesis-oriented analysis of the outcomes achieved during its implementation and operation. Unlike earlier deliverables D7.1 [1], D7.2 [3] and D7.3 [2] that focus on planning, technical setup and execution, D7.4 consolidates operational experience, lessons learned and market-oriented insights with the objective of supporting replication, scaling and exploitation of EV-based flexibility solutions.

In this context, D7.4 is closely related to the corresponding deliverables of the other EV4EU demonstrators, namely Deliverable D6.4 Evaluation and lessons learned of the Azores demo [4], D8.5 Analysis of demonstration results in the Greek demonstration report [5], Deliverable D8.6 Lessons learned in Greek Demonstrator and Services/Tools Marketability report [6], Deliverable D9.4 Demonstration results report for the Danish demo [7], and Deliverable D9.5 Lessons learned, impact and replicability potential assessment for the Danish demo [8], impact and replicability potential assessment for the Danish demo. While these deliverables document the implementation and performance of individual demonstrations, D7.4 contributes a cross-cutting perspective by translating demonstration experience into structured lessons learned and marketability assessments.

The Slovenian demonstrator activities analysed in this deliverable are grounded in the preparatory and implementation work carried out in earlier WP7 deliverables. In particular, Task T7.1 resulted in the final specification of the Business Use Cases (BUCs) to be tested in Slovenia, building on the use cases defined in Task T1.5 and documented in Deliverable D1.5 – V2X Use-cases repository [9]. These specifications formed the basis for Deliverable D7.1 – Detailed definition and implementation plan of the Slovenian demonstrator [1], which defined the technical and operational setup.

The implementation and commissioning of the Slovenian demonstrator were subsequently documented in Deliverable D7.2, which translated the original plans into practical deployment and operational procedures [3]. Deliverable D7.3 – Slovenian use cases demonstration, monitoring and evaluation report [2] then provided a quantitative assessment of demonstrator performance, including KPIs and measured impacts across the implemented use cases.

Deliverable D7.4 builds directly on D7.3 [2] by moving beyond performance reporting towards qualitative interpretation and synthesis. It uses the monitored results, KPIs and operational observations to identify root causes, enabling factors and limitations, and to assess the marketability and exploitation potential of the demonstrated services.

In addition, D7.4 draws on knowledge developed in other work packages, particularly D1.4 – Business models centred in the V2X value chain [10], which informed the business logic of the Slovenian use cases, and D1.3 – Regulatory opportunities and barriers for V2X deployment in Europe [11], which provided the regulatory context for market and operational analysis. Insights related to

communication and interoperability are aligned with D5.1 – Information exchange needs to enable different use cases [12] and D5.2 – Standardisation gap analysis for new V2X-related business models [13].

Furthermore, several strategies, services and algorithms developed under Tasks T4.3 and T4.4, documented in D4.3 – Optimal management of V2X flexibilities integrated into a Virtual Power Plant portfolio [14] and D4.4 – Impact of mass deployment of V2X in energy markets and services [15] were evaluated in practice within the Slovenian demonstrator. The operational experience gained from testing these developments constitutes an important input to the lessons learned and marketability assessment presented in this deliverable.

Overall, Deliverable D7.4 represents the culmination of the Slovenian demonstrator activities, linking design, implementation and evaluation deliverables with exploitation-oriented conclusions. It provides a coherent bridge between technical demonstration results and forward-looking recommendations for future deployment of EV-based flexibility within and beyond the EV4EU project.

2 Overview of the Slovenian Demonstrator

Within the EV4EU project, the Slovenian demonstrator has been developed as a comprehensive pilot environment to validate the integration of electric vehicles into the energy system through V2X (vehicle-to-everything) technologies. The project has focused on deploying bidirectional charging infrastructure, integrating electric vehicles into a virtual power plant (VPP), and enabling their participation in electricity markets and grid services. Through collaboration between GEN-I, Elektro Celje, the University of Ljubljana, and ABB, the demonstrator combines real infrastructure, user participation, and advanced control platforms to test technical solutions, evaluate business models, and assess the role of electric vehicles in providing flexibility and supporting grid stability.

The Krško demonstrator represents the core operational site of the Slovenian pilot, where V2X chargers are deployed at the GEN-I office building. Its primary objective is to demonstrate the management of electric vehicles through a virtual power plant and to validate their participation in electricity markets and ancillary services. The installation enables bidirectional energy flows, allowing electric vehicles to act as distributed battery storage units and actively support grid stability. This site provides real-world conditions like real-world charger/VPP activation and platform-emulated market workflow for testing the interaction between aggregators, system operators, and market platforms, making it a key environment for validating flexibility services.

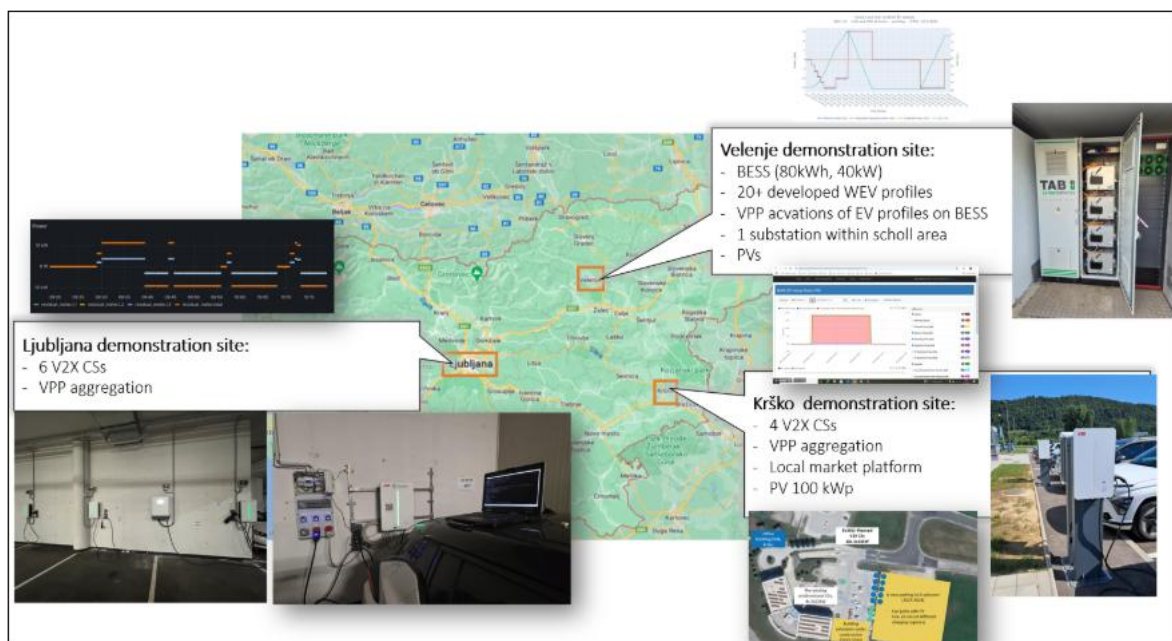


Figure 1: Slovenian demonstration locations

The Ljubljana demonstrator complements the Krško site by introducing an urban use case, where V2X charging infrastructure is installed at a GEN-I office building. It focuses on studying user interaction, optimizing charging processes, and integrating electric vehicles into local flexibility markets with minimal impact on user behaviour. The demonstrator supports the upgrade of virtual power plant functionalities and local market platforms, enabling electric vehicles to participate as active assets in

the energy system. This environment is particularly relevant for validating scalable business models and services in real-life urban conditions.

The Velenje demonstrator is centred on the use of a battery energy storage system (BESS) and the simulation of electric vehicle behaviour within flexibility services. Its purpose is to analyse the potential of V2X solutions and to support the development of aggregation strategies within a virtual power plant. By combining data from distributed sources and modelling EV profiles, this demonstrator enables the testing of algorithms for flexibility activation and market participation. It serves as an important analytical and development platform, supporting the design and scaling of future implementations.

2.1 Demonstrator Objectives and Setup

The Slovenian demonstrator has been developed within the EV4EU project as a comprehensive pilot aimed at demonstrating the active role of EVs in future energy systems. The demonstrator addresses one of the key challenges of the energy transition: how to integrate a rapidly growing number of EVs into electricity grids and markets in a way that supports system stability, enables higher penetration of renewable energy sources, and creates economically viable flexibility services. Rather than treating EV charging as an additional burden on the grid, the Slovenian demonstrator explores how EVs can be turned into a flexible, distributed resource through V2X concepts, aggregation, and market-based coordination.

The Slovenian demonstrator aimed to validate the integration of EV-based flexibility into electricity system operations under real-world conditions. The demo was implemented across several locations and combined EVs, charging infrastructure, ICT platforms, and a BESS used to emulate larger EV fleets where necessary. A virtual power plant aggregated the available flexibility and enabled interaction with DSO systems. Both V1G and V2X charging concepts were tested to assess different levels of controllability, complexity, and system value.

At its core, the Slovenian demonstrator focuses on the interaction between EVs, a VPP, electricity markets, and the distribution grid. The demonstrator is designed to validate advanced V2X strategies under real and near-real operating conditions, covering both technical integration and market readiness. A key objective is to show that EV-based flexibility can be reliably activated without compromising user comfort, while at the same time delivering tangible benefits for aggregators, DSOs, and the overall power system. This approach reflects a shift from purely technology-driven pilots towards solutions that are aligned with real operational practices and regulatory frameworks.

The scope of the Slovenian demonstrator is defined through a set of interrelated EV4EU use cases that together cover the full flexibility value chain. These include V2X management by a VPP, participation of EVs in electricity and flexibility markets, provision of grid services, and activation of flexibility by the DSO. By addressing these use cases jointly, the demonstrator enables an integrated assessment of EV flexibility across multiple system layers, rather than analysing individual services in isolation. This holistic perspective is particularly relevant in the context of increasing system complexity, where flexibility resources are expected to deliver value simultaneously at market, system, and local grid levels.

The demonstrator is implemented across several physical and virtual locations in Slovenia, combining office-based charging infrastructure, and simulation-based environments. GEN-I office buildings in Krško and Ljubljana serve as key pilot sites, hosting smart and V2X-capable charging stations that are integrated into the aggregator's VPP platform. In addition, demo site in Krško was connected with the

Elektro Celje distribution system. To complement the limited availability of bidirectional EVs and to enable scalable analysis, BESS and EV profile simulations are used to emulate larger EV fleets and assess system-level impacts of flexibility activation. This hybrid approach allows the demonstrator to balance real-world testing with controlled experimentation, ensuring both realism and analytical depth.

A defining characteristic of the Slovenian demonstrator is the strong emphasis on aggregation and automation. EVs are aggregated within the GEN-I VPP together with other distributed energy resources, such as renewable generation and storage. Flexibility is managed centrally by the VPP, which optimises charging and discharging schedules based on market signals, grid needs, and user constraints. The demonstrator follows a clear principle of minimal interaction with EV users: users are not required to actively manage charging behaviour but instead define boundary conditions such as availability windows and minimum state-of-charge requirements. Within these constraints, the VPP autonomously orchestrates flexibility provision, reflecting conditions that are essential for mass-market adoption of V2X services.

From a market perspective, the Slovenian demonstrator investigates how aggregated EV flexibility can participate in electricity markets and flexibility services in a structured and economically meaningful way. This includes the assessment of bidding strategies, service procurement processes, and activation schemes across different market layers. Particular attention is given to the compatibility between market mechanisms and local grid requirements, as misalignment between these layers is increasingly recognised as a barrier to large-scale flexibility deployment. By integrating EV-based flexibility into a VPP that already operates in existing markets, the demonstrator provides valuable insights into how V2X can be embedded into current market structures rather than relying on parallel or experimental market setups.

In parallel, the demonstrator explicitly addresses the needs of the DSO. Elektro Celje plays an active role in defining grid-related flexibility requirements and in testing different modes of flexibility activation, including both manual and automated processes. The demonstrator examines how EV flexibility can help mitigate local grid issues such as congestion or voltage deviations, and how DSO decision-making can be supported through digital interfaces and data exchange with the VPP. This DSO-centric perspective is crucial, as the impact of EV charging is often most pronounced at the local distribution level, where traditional grid reinforcement solutions are costly and slow to implement.

The Slovenian demonstrator operates within a regulatory environment that increasingly supports flexibility services, aggregation, and the participation of new market actors. Slovenian legislation, aligned with EU energy market directives, provides a legal foundation for VPP operation, flexibility markets, and DSO procurement of services. This regulatory context enables the demonstrator to focus not only on technical feasibility, but also on compliance and replicability. As a result, the solutions tested in the Slovenian demonstrator are closely aligned with current and anticipated regulatory conditions, increasing their relevance for wider deployment beyond the project duration.

Equally important is the collaborative nature of the demonstrator. GEN-I, Elektro Celje, the University of Ljubljana, and ABB jointly cover the roles of aggregator, DSO, CPO, research institution, and technology provider. This multi-actor setup ensures that technical developments are continuously validated against operational realities, market logic, and system constraints. The involvement of academic partners supports rigorous performance evaluation and data analysis, while industrial partners ensure that the demonstrated solutions remain connected to commercial product development and service design.

Within the EV4EU project as a whole, the Slovenian demonstrator serves as a reference case for advanced, market-oriented V2X deployment in a medium-sized European power system. Its focus on

real stakeholders, operational processes, and regulatory alignment makes it particularly valuable for identifying both opportunities and barriers related to EV-based flexibility. The experiences gathered through the design, implementation, and operation of the demonstrator provide a solid foundation for analysing lessons learned and assessing the marketability of the proposed solutions, which are the central focus of this deliverable.

2.2 Demonstrated Use Cases

The Slovenian use cases focus on the practical implementation of EV based flexibility across different operational layers of the electricity system. The demonstrated use cases were selected to reflect realistic roles of electric vehicles in future energy systems, considering the maturity of available technologies, regulatory conditions, and market structures in Slovenia. Each use case addresses a specific aspect of flexibility utilisation, while together they form a coherent framework that links aggregation, market participation, and grid-oriented activation.

A central element of the Slovenian use cases is the role of aggregation, where electric vehicles are managed collectively rather than individually. The use case related to V2X management by a Virtual Power Plant demonstrates how EVs can be integrated into an existing aggregation environment and treated as controllable flexibility assets. In this use case, EV charging behaviour is not fixed or static, but dynamically adjusted over time based on system-level objectives. The VPP optimises charging schedules by considering EV availability patterns, user-defined constraints, and overall flexibility potential, thereby enabling coordinated control without direct user intervention. This use case establishes the operational foundation upon which the remaining Slovenian use cases are built.

Extending beyond internal optimisation within the VPP, the Slovenian demonstrator further implements a use case focused on the participation of V2X resources in electricity markets. Here, aggregated EV flexibility is made available for market-based coordination, allowing EV charging demand to respond to economic signals. The use case evaluates how EV flexibility can be aligned with market requirements despite the inherent variability and uncertainty of mobility-driven assets. By participating in electricity markets through an aggregator, EVs are positioned alongside other flexible resources, contributing to system balancing and efficiency while remaining transparent to end users. This use case highlights the conditions under which EVs can become a market-relevant resource rather than a passive load.

In parallel with market participation, Slovenian use cases explicitly address the interaction between electric vehicles and the distribution grid. The use case dedicated to the provision of grid services by V2X resources explores how aggregated EV flexibility can support local grid operation. Instead of reinforcing grid infrastructure, flexibility from EV charging is used to mitigate operational constraints at the distribution level. Charging profiles are adjusted in response to network needs, demonstrating how EVs can contribute to congestion management and improved grid performance. This use case reflects an increasingly important role of flexibility at the distribution level, where the impact of electrification is most directly felt.

A further evolution of grid-oriented flexibility is demonstrated through the use case of DSO-driven activation of V2X services. In this case, the DSO takes an active role in identifying flexibility needs based on grid conditions and initiating flexibility activation through defined interfaces. The use case is

implemented in both manual and automated forms, allowing the assessment of different operational approaches to flexibility activation. This includes evaluating how DSO requests are translated into actionable control signals by the aggregator and ultimately executed at the level of EV charging infrastructure. The demonstrated workflows provide insights into the coordination requirements between DSOs and aggregators, which are essential for large-scale deployment of flexibility services.

An important aspect across all Slovenian use cases is the coexistence of multiple flexibility objectives. Market-based optimisation and grid-based activation are not treated as isolated or sequential processes, but as interdependent layers that must be aligned. The Slovenian demonstrator therefore implements use cases in which EV flexibility is first aggregated and assessed at system level, and only subsequently allocated to market or grid services depending on prevailing conditions. This approach reflects emerging flexibility frameworks in Europe, where resource allocation must balance economic efficiency with operational security.

To enable robust evaluation of the Slovenian use cases, a hybrid demonstration approach is applied. Real charging infrastructure and EVs are complemented by simulated EV profiles and battery storage systems, allowing the assessment of use case behaviour under a broader range of scenarios than would be possible with physical assets alone. This approach ensures that the use cases are evaluated not only for technical feasibility, but also for scalability and performance under varying penetration levels of electric vehicles.

Overall, the Slovenian use cases provide a structured demonstration of how electric vehicles can move beyond uncontrolled charging towards an active and coordinated role in electricity systems. Each use case contributes a specific functional perspective, while together they demonstrate an integrated flexibility framework that links aggregation, markets, and grid operation. The insights gained from implementing and operating these use cases form the basis for the identification of key lessons learned and for assessing the potential of these solutions to be transferred into market-ready services.

The Slovenian demo addressed use cases UC9 to UC12, covering:

- aggregation and control of EV-based flexibility within a VPP,
- participation of EVs in electricity and flexibility markets,
- provision of grid services to the DSO,
- technical and operational integration with DSO systems and ADMS.

Together, these use cases provided a comprehensive view of the EV flexibility value chain.

3 PART I – LESSONS LEARNED FROM THE SLOVENIAN DEMONSTRATOR

The Slovenian demonstrator provided an extensive practical framework for testing, operating, and evaluating advanced EV based flexibility solutions under realistic technical, market, and regulatory conditions. While the previous sections of this deliverable describe the demonstrator setup and the implemented use cases, this chapter focuses on the systematic analysis of the lessons learned during the design, implementation, operation, and evaluation phases of the Slovenian demonstration activities.

The lessons learned are derived from hands-on experience gained throughout the entire lifecycle of the Slovenian demonstrator, including infrastructure deployment, system integration, operation of the use cases, interaction between involved stakeholders, and performance evaluation. These insights go beyond purely technical results and reflect practical challenges, enabling factors, and limitations encountered when moving V2X solutions from conceptual design towards real-world application. As such, they represent an essential input for assessing the maturity and transferability of the demonstrated solutions.

Given the complexity of the Slovenian demonstrator and the diversity of actors involved, lessons learned are not limited to a single dimension. Instead, they span multiple domains, including technology readiness, system integration, operational processes, data availability and quality, regulatory and market aspects, as well as organisational and stakeholder coordination. To capture this multidimensional character, the lessons are structured and analysed across distinct thematic areas, allowing for a clearer understanding of how different factors influence the successful deployment of EV-based flexibility solutions.

This thematic structuring enables the identification of cross-cutting patterns and interdependencies between technical, market, and organisational aspects, while also highlighting domain-specific insights. In doing so, the analysis supports a transparent assessment of which elements of the Slovenian demonstrator are already sufficiently mature for broader deployment and which areas require further development, adaptation, or regulatory clarification. The lessons learned thus serve both as feedback on the Slovenian demonstration itself and as guidance for future large-scale roll-out of similar solutions within and beyond the Slovenian energy system.

The findings presented in this chapter form the conceptual bridge between the demonstrated use cases and the subsequent assessment of service marketability. By analysing lessons learned across different domains, this section lays the groundwork for identifying realistic pathways toward commercially viable solutions and for understanding the conditions under which V2X-based services can be sustainably introduced into energy markets and grid operation practices in the future.

In summary, the Slovenian demonstrator showed that EV-based flexibility and aggregation concepts are transferable beyond a single pilot environment, but their large-scale deployment is highly context-dependent. Scalability is conditioned by local EV penetration, regulatory readiness, availability of V2X-capable assets, and the digital and organisational maturity of DSOs and aggregators. The lessons learned confirm that a phased and incremental deployment strategy, starting with V1G and gradually introducing V2X, represents a low-risk and realistic pathway for replicating solutions and scaling EV-based flexibility across different regions and electricity systems.

The lessons learned can be grouped into complementary domains that collectively determine the feasibility of scaling EV-based flexibility solutions. As illustrated in Figure 2, technical and operational

readiness must be accompanied by appropriate regulatory frameworks, data availability, market conditions, and stakeholder acceptance. Only when these elements are jointly addressed can pilot-level solutions be successfully replicated and scaled.

Figure 2 summarises the key lessons learned from the Slovenian demonstrator across technical, operational, market, regulatory, data-related, and stakeholder domains. Together, these lessons define the conditions for replicability and support a phased scaling strategy, where unidirectional smart charging (V1G) represents the initial step, followed by the gradual introduction of V2X solutions as system maturity increases.

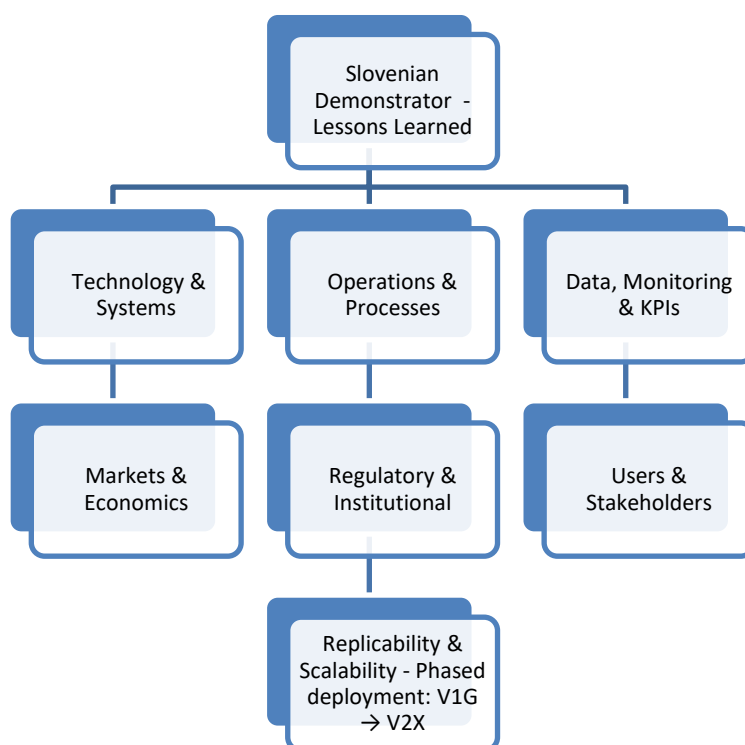


Figure 2: Diagram of lessons learned from Slovenian demonstrator

The Slovenian demonstrator provided valuable insights into the technical maturity and integration challenges of V2X solutions within an existing energy system landscape. Lessons learned in this area relate primarily to the interoperability between charging infrastructure, EVs, aggregation platforms, and DSO systems, as well as to data communication, measurement availability, and system robustness. The demonstrator confirmed that while the core technologies required for EV-based flexibility are largely available, their integration into a coherent and reliable operational system requires significant effort, careful coordination, and iterative testing. These experiences highlight the importance of standardisation, flexible system architectures, and realistic assumptions regarding technology readiness when planning similar deployments.

During the implementation of the Slovenian demonstrator, it became evident that the technological development of the V2X ecosystem did not fully progress in line with the initial assumptions and timelines defined in the EV4EU project proposal. In particular, the market availability of V2X-capable electric vehicles, the maturity of relevant standards in commercial deployments, and the pace of OEM adoption evolved more slowly and unevenly than originally anticipated. In response to these

developments, the demonstrator approach was continuously adapted, with the introduction of alternative technical solutions and supporting assets where necessary. This included the increased use of V1G, BESS, and simulation-based methods to ensure that the core objectives of flexibility evaluation, aggregation, and system integration could still be achieved. These adaptations proved essential for maintaining the relevance and continuity of the demonstrator activities and provided valuable insights into the importance of flexibility and resilience in demonstrator design for rapidly evolving technological domains such as V2X.

3.1 Technical lessons learned

The implementation of the Slovenian demonstrator within the EV4EU project resulted in a significant technological and systemic advancement in the field of EV-based flexibility. The project successfully moved beyond conceptual development and laboratory validation by deploying and operating complex flexibility solutions in real distribution network conditions. This enabled a comprehensive assessment of technical maturity, operational feasibility and market relevance, providing valuable insights that would not be achievable through simulation-based approaches alone.

A broad set of innovations and KERs were developed, integrated and tested, covering communication standards, charging and aggregation technologies, digital platforms, operational coordination mechanisms and business concepts. The demonstrator confirmed that EV-based flexibility has progressed from an emerging concept to a technically viable and system-relevant solution, capable of supporting distribution grid operation and contributing to the broader energy transition. In several areas, the project achieved a clear step forward compared to the state of practice, particularly with regard to system integration, interoperability between actors and the coordinated use of EVs as flexible assets.

At the same time, the demonstrator provided a realistic view of the challenges that accompany such technological progress. The complexity of real-world deployment revealed important gaps between theoretical readiness and practical implementation, particularly in relation to standardisation maturity, system reliability, regulatory frameworks and user behaviour. These insights form the basis for the lessons learned presented in the following sections, which reflect not only technical findings, but also operational, regulatory and market-oriented experiences.

By capturing both achievements and limitations, the lessons learned from the Slovenian demonstrator represent a key outcome of the project. They provide concrete guidance for future deployments, support more realistic exploitation strategies and contribute to the development of EV-based flexibility as a credible, scalable and economically viable component of future electricity systems.

3.1.1 Technology Maturity and standardisation

The Slovenian demonstrator clearly highlighted the distinction between the formal existence of technical standards and their effective maturity in real-world deployments. Although key communication and charging standards relevant for V2X, such as ISO 15118-20 and OCPP, are already defined, their practical implementation across vehicles, charging stations and backend systems remains uneven. Differences in vendor interpretation, partial feature support and varying implementation timelines resulted in additional integration effort, custom configurations and limited interoperability during the demonstration.

A key lesson learned is that standardisation alone is not sufficient to guarantee seamless deployment of EV-based flexibility services. Practical maturity depends not only on the availability of standards, but

also on vendor support, certification procedures, testing practices and backward compatibility with legacy systems. The demonstrator experience shows that future deployments must place stronger emphasis on early and comprehensive validation of standard implementations across all involved components. Such early validation is essential to reduce project risk, avoid late-stage integration challenges and ensure predictable system behaviour in operational conditions.

3.1.2 EV and Charging Infrastructure

The Slovenian demonstrator clearly highlighted that the availability and maturity of V2X-capable electric vehicles remain one of the key limiting factors for the large-scale deployment of advanced V2X services. Although technical standards for bidirectional charging already exist, their practical availability on the market is still limited. This gap between standardisation and market readiness required close cooperation with vehicle manufacturers and, in parallel, the use of alternative assets such as BESS and simulated EV profiles to ensure comprehensive testing of the proposed use cases. These experiences confirm that, at present, the pace of V2X deployment is not primarily constrained by conceptual feasibility, but rather by the slow market penetration of compatible vehicles.

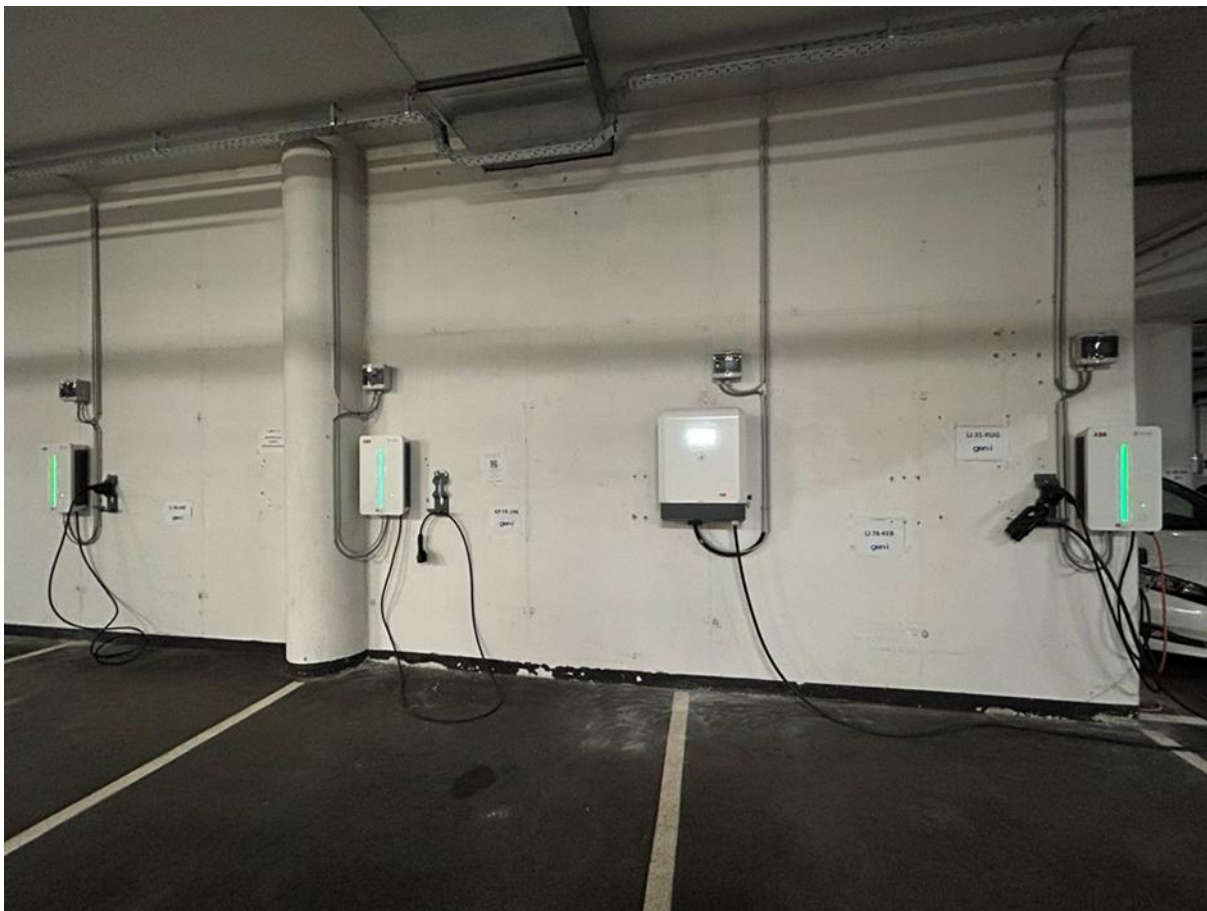


Figure 3: V2X charging stations at the demo location in Ljubljana

In addition to vehicle availability, the demonstration underlined the critical importance of charging infrastructure reliability and full compliance with grid requirements. The charging points act as a central interface between EVs, aggregators, and the electricity system. Even minor technical issues at the charging point level were shown to have a cascading impact across the entire flexibility chain,

affecting aggregation, monitoring, and service delivery. Ensuring stable operation, proper certification, and robust grid compliance of charging infrastructure therefore emerged as a fundamental prerequisite for any V2X-based flexibility service.

3.1.3 VPP and Aggregation Architecture

The integration of electric vehicles into a Virtual Power Plant portfolio proved to be technically feasible, but operationally more complex when compared to the aggregation of stationary assets. Unlike stationary resources, EV availability is inherently uncertain and strongly influenced by user behaviour, mobility patterns, and charging habits. This characteristic necessitated the use of advanced forecasting, continuous monitoring, and adaptive control strategies in order to maintain reliable flexibility provision at the aggregated level. The demonstrator experience showed that treating EVs in the same way as conventional flexible assets is insufficient without dedicated mechanisms to manage uncertainty and variability.

A comparative assessment between V1G and V2X provided additional insights. V1G solutions were identified as offering a significantly lower entry barrier in terms of technical complexity, integration effort, and operational risk. At the same time, V2X solutions demonstrated a higher potential system value, particularly in scenarios requiring active flexibility provision. This higher value, however, comes at the cost of increased technical, operational, and coordination complexity. These findings suggest that V1G and V2X should not be viewed as competing approaches, but rather as complementary steps along a gradual deployment pathway.

3.1.4 ICT, Data, and System Integration

Reliable communication and data exchange were confirmed as essential enablers for the successful operation of EV-based flexibility services. The Slovenian demonstrator demonstrated that existing communication protocols and aggregation platforms are in principle capable of supporting EV flexibility. However, practical implementation revealed that integration with DSO systems requires harmonised data models, clearly defined interfaces, and consistent data quality across all involved systems.

Particular attention was required for the alignment of data formats, temporal resolutions, and signal definitions between aggregator platforms and DSO operational tools. Without such alignment, the risk of misinterpretation or delayed response increases, which can undermine trust in flexibility solutions. In addition, the demonstration highlighted the importance of robust cybersecurity and access control mechanisms, especially given the increasing number of interconnected systems and stakeholders involved.

At the same time, a key remaining challenge lies in the interaction with electric vehicles themselves. Many EV models currently do not support V2X functionality or provide limited communication capabilities, which restricts their ability to participate in flexibility services. This limitation highlights the need for further standardisation, wider OEM support, and improved interoperability between vehicles and external control platforms. These lessons underline that ICT integration, including EV communication readiness, should be treated as a core component of flexibility deployment rather than as a secondary technical detail.

3.1.5 System Reliability and Fail-Safe Design

Another important technical lesson from the Slovenian demonstrator concerns system reliability and the need for robust fail-safe operational concepts. EV-based flexibility services rely on a large number of distributed components, including vehicles, charging infrastructure, communication networks and backend platforms. Each of these elements may fail, become temporarily unavailable or behave unpredictably due to technical issues or user behaviour.

No critical system-wide failure case requiring emergency intervention was observed during the Slovenian demonstrator operation; however, several minor disruptions and component-level inconsistencies (e.g. communication interruptions, temporary asset unavailability, and charger-specific issues identified in related testing activities) confirmed the necessity of robust fallback mechanisms. Notably, one charging station completely failed during the testing period due to an internal electrical fault, resulting in a full loss of functionality. In such cases, the affected charging unit is replaced with a new one to ensure continuity of operations and restore full system capability. In parallel, predefined failsafe strategies—such as conservative activation limits, automated fallback modes, and reliance on complementary flexibility resources—were available and considered essential for maintaining system stability. While these fallback mechanisms were not triggered as part of a large-scale failure event, their presence proved crucial for ensuring reliable operation under non-ideal conditions and mitigating potential risks associated with distributed and heterogeneous system components.

The demonstrator confirmed that robust fallback mechanisms are essential to ensure that grid operation is not compromised in the event of communication failures, asset unavailability or unexpected deviations from planned behaviour. Conservative activation strategies clearly defined operational limits and automated fallback modes proved critical for maintaining system stability. A further key insight is that EV-based flexibility should be treated as a complementary resource rather than a single point of dependency. Combining EVs with other flexible assets, such as battery energy storage systems, significantly increases overall system resilience and reduces operational risk.

3.2 Operational and Process-Related Lessons Learned

From an operational perspective, the Slovenian demonstrator revealed important lessons related to the day-to-day execution of flexibility use cases and the coordination between involved stakeholders. The transition from planned operational workflows to real execution exposed gaps between theoretical process definitions and practical constraints, such as timing, data availability, and stakeholder responsiveness. The experience shows that well-defined operational procedures, clear division of responsibilities, and strong coordination mechanisms are critical for ensuring reliable flexibility activation. Furthermore, operational complexity increases significantly when multiple use cases and activation paths are executed in parallel, underlining the need for simplicity and automation where possible.

3.2.1 Aggregator and VPP Operation

From an operational perspective, the demonstration showed that EV-based flexibility requires continuous and active coordination between aggregators, charging point operators, and end users.

One of the main operational challenges identified was managing uncertainty in EV availability while still ensuring predictable and reliable service delivery. Unlike traditional flexibility assets, EVs cannot be fully committed without accounting for real-time changes in user behaviour and availability.

The experience from the Slovenian demonstrator highlighted the importance of clearly defined operational procedures, supported by robust fallback strategies. Such mechanisms are essential to maintain service reliability when expected flexibility cannot be fully delivered. These operational lessons indicate that successful EV aggregation depends not only on control algorithms, but also on well-designed operational frameworks that anticipate deviations and provide predefined responses.

3.2.2 DSO Interaction and Grid Operation

The demonstrator confirmed that DSO can technically integrate aggregated EV flexibility into grid operation processes. However, the experience also showed that successful utilisation of such flexibility depends strongly on non-technical factors. Trust, transparency, and predictability emerged as critical prerequisites for DSO engagement. DSOs require confidence that requested flexibility will be delivered as agreed and that activation of EV-based services will not compromise grid security or operational safety.

The lessons learned emphasise the need for clear communication channels, transparent activation logic, and well-defined responsibilities between DSOs and aggregators. Building operational trust was identified as a gradual process, supported by repeated successful activations and clear performance monitoring. These findings highlight that DSO–aggregator interaction is as much an organisational challenge as it is a technical one.

Another main lesson learned from the Slovenian pilot is that local flexibility markets can significantly improve DSO observability and operational control of distribution networks, but only if the supporting market platform is sufficiently interoperable, automated and scalable. In the current implementation, the FlexIS platform (Figure 4) is primarily focused on supporting local flexibility procurement through seasonal tenders and bilateral contractual arrangements. The platform is integrated with the Slovenian national data hub unified entry point (EVT), which acts as an intermediary layer for the registration of flexibility providers, publication of tenders, forwarding of bids and activation requests. In this setup, the DSO remains responsible for bid evaluation and activation decisions, while communication with aggregators is largely routed through EVT. Current demonstrations confirmed that this architecture enables reliable operation of flexibility services and supports both manual and automatic activation of contracted flexibility resources directly from ADMS and Lambda-based grid analytics.

Operational experience also highlighted several limitations of the current approach. The present implementation supports a limited number of flexibility service providers and mainly relies on seasonal or long-term procurement mechanisms, which reduces market liquidity and limits the ability of DSOs to dynamically react to rapidly changing grid conditions. In practice, the current process still depends on predefined contractual relationships and static flexibility reservations, which are less suitable for highly dynamic low-voltage (LV) and medium-voltage (MV) congestion management scenarios.

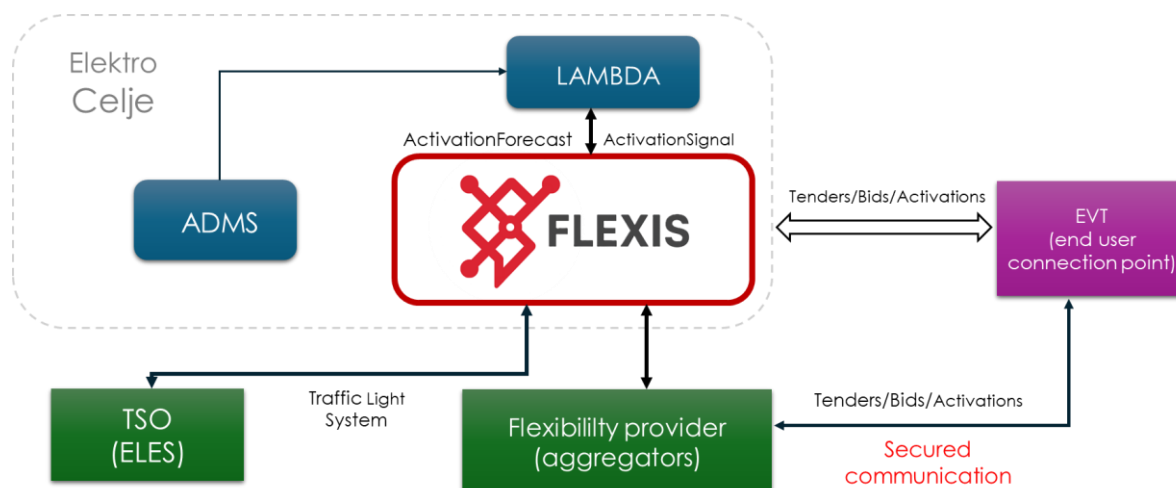


Figure 4: FlexIs

Future developments of local flexibility markets should therefore move towards more dynamic and automated procurement processes. Day-ahead flexibility auctions, automated qualification and registration of flexibility providers, and direct communication between aggregators and local flexibility platforms will be necessary to ensure faster and more efficient procurement of flexibility services based on actual operational needs of the distribution network. Future architectures should also support interoperable interfaces with aggregators and VPPs using standardised CIM ESMP profiles, XML/JSON exchanges and modern streaming communication protocols such as MQTT, AMQP and Apache Kafka.

Another important lesson learned is that flexibility activation requires near real-time interaction between market processes and grid operation tools. The Slovenian pilot demonstrated that the combination of ADMS observability, short-term forecasting and automated activation workflows can provide DSOs with an effective operational tool for congestion management and voltage regulation without immediate reinforcement of physical infrastructure. In the future, this approach should evolve towards technology-agnostic flexibility integration, enabling participation of heterogeneous flexibility resources including EVs, battery storage systems, photovoltaics (PV) and industrial demand response (DR) resources.

3.2.3 Coordination Between Operational Layers

The coordination between operational layers, particularly between DSOs, aggregators and the TSO is related to another key lesson. In the current implementation, TSO–DSO coordination is only partially supported. The existing architecture mainly enables DSO-driven local flexibility activation, while the TSO does not yet have direct operational access to market information, activation statuses or real-time flexibility availability within the distribution system. Although the Slovenian pilot demonstrated successful interaction between ADMS, Lambda, FlexIS, EVT and the aggregators VPP, coordination mechanisms between local flexibility markets and national balancing markets remain limited.

The pilot clearly demonstrated that future large-scale flexibility utilisation will require significantly stronger coordination between operational and market layers. Local flexibility markets and balancing markets cannot operate independently if the same flexibility resources are expected to participate

simultaneously in both environments. Future market frameworks should therefore support harmonised products, interoperable communication models and transparent exchange of operational constraints between TSOs and DSOs.

Future operational frameworks should also introduce standardised interfaces enabling controlled TSO access to selected market and operational data from local flexibility platforms. Such interfaces should provide information about qualified flexibility providers, available flexibility volumes, activation status, market results and geographical location of flexibility resources connected to the distribution network. Additional focus should be placed on the use of CIM ESMP standards and interoperability with ENTSO-E balancing market profiles, enabling future integration of local flexibility markets with balancing and reserve markets.

An additional lesson learned is that operational coordination cannot rely solely on market-level interactions. The Slovenian pilot highlighted the importance of real-time operational signals and ADMS-based network assessments, especially when flexibility activations may simultaneously affect both distribution and transmission system operation. Future coordination mechanisms should therefore combine market coordination with operational security constraints, enabling DSOs and TSOs to jointly optimise the utilisation of distributed flexibility resources while maintaining secure and stable operation of the overall power system.

3.3 Flexibility Management and Use Case Execution Lessons Learned

Managing EV-based flexibility across multiple use cases highlighted several lessons related to predictability, controllability, and performance of EV fleets as flexibility resources. The Slovenian demonstrator showed that EV flexibility is inherently variable and strongly influenced by user behaviour, availability patterns, and technical constraints of vehicles and charging infrastructure. While aggregation significantly improves reliability, differences between expected and realised flexibility remain an important consideration. These lessons emphasise the need for conservative flexibility forecasting, adaptive control strategies, and continuous monitoring when integrating EVs into operational flexibility portfolios.

3.3.1 Flexibility Management

The Slovenian demonstrator provided important insights into the practical management of flexibility derived from electric vehicles within an aggregated portfolio. One of the key lessons learned was that EV-based flexibility differs fundamentally from conventional and stationary flexibility resources. Its availability is dynamic and strongly influenced by external factors such as user behaviour, mobility needs, and charging habits. As a result, flexibility management required continuous forecasting updates, real-time monitoring, and adaptive control mechanisms to account for deviations between expected and actual flexibility.

The experience demonstrated that aggregation plays a crucial role in mitigating individual EV uncertainty; however, aggregation alone is not sufficient to guarantee predictable flexibility delivery. Conservative flexibility estimation and the inclusion of safety margins proved necessary to ensure reliable operation. Furthermore, coordinating EV flexibility with other assets within the Virtual Power Plant portfolio improved overall controllability but increased operational complexity. These lessons

highlight that effective flexibility management for EVs requires dedicated strategies and tools, rather than direct reuse of approaches developed for traditional flexibility assets.

3.3.2 Use Case Execution

The execution of the Slovenian use cases under real and near-real operating conditions highlighted several lessons related to the translation of use case design into practical implementation. While the conceptual definition of the use cases was robust, their execution revealed gaps between planned workflows and real-world constraints, particularly regarding timing, data availability, and system coordination. Successfully executing use cases across market-based and grid-oriented scenarios required close alignment between aggregation logic, operational procedures, and external system conditions.

Another key lesson learned was the interdependence between different use cases. Actions taken within one use case, such as market-oriented optimisation, could directly influence the availability and performance of flexibility in another use case, such as grid service provision. This necessitated prioritisation mechanisms and clear decision hierarchies to manage potential conflicts. The demonstrator experience confirmed that use case execution should be supported by flexible and modular implementation approaches, allowing adjustments during operation without compromising overall system stability.

3.4 Market and Economic Lessons Learned

The demonstration of EV participation in market-oriented flexibility mechanisms provided important insights into the economic viability and scalability of V2X services. Lessons learned in this area relate to the alignment between technical flexibility potential and market rules, the role of aggregation in reducing uncertainty, and the limitations imposed by current market designs. The Slovenian demonstrator experience suggests that while EV-based flexibility can create system value, translating this value into sustainable revenue streams remains challenging under existing market conditions. These findings are particularly relevant for understanding the gap between technical feasibility and commercial deployment.

3.4.1 Market Participation

The Slovenian demonstrator highlighted that existing electricity, and flexibility markets are not yet fully adapted to the specific characteristics of EV-based flexibility resources, particularly at the distribution level. Although aggregation enables EVs to participate beyond individual asset limitations, several structural market barriers remain. Minimum bid sizes, rigid product definitions, and settlement rules are typically designed for conventional and stationary flexibility assets, which restrict the effective participation of aggregated EV fleets.

The experience from the demonstration showed that these constraints limit both the frequency and the economic attractiveness of EV participation in current market frameworks. In particular, the temporal characteristics and availability profiles of EVs are not always well aligned with existing market products. These findings indicate that further market design adaptations are required to fully unlock

the potential of EV flexibility, especially in local and distribution-level flexibility schemes. The demonstrator revealed several important lessons related to the interaction between EV-based flexibility and existing electricity and flexibility markets. Although aggregation enables electric vehicles to overcome individual asset limitations, current market frameworks are still largely designed around conventional and stationary flexibility resources. As a result, aggregated EV flexibility often does not naturally fit within existing market structures, particularly at the distribution level.

Key market-related constraints identified during the demonstration include minimum bid sizes, rigid product definitions, and settlement rules that do not adequately reflect the distributed, variable, and user-dependent nature of EV flexibility. These constraints limit the ability of aggregated EVs to participate regularly and efficiently in current markets, even when sufficient technical flexibility is available. In practice, this leads to underutilisation of EV flexibility potential and reduces incentives for aggregators to actively engage EVs in market-based services.

The lessons learned indicate that dedicated flexibility products, adapted bidding conditions, and market mechanisms that explicitly account for aggregation and uncertainty are necessary to enable meaningful participation of EV-based resources. Without such adaptations, EV flexibility is more likely to remain confined to demonstration environments or ad-hoc arrangements rather than becoming an integral part of regular market operation.

3.4.2 Economic Lessons Learned

From an economic perspective, the demonstrator highlighted the gap between technical value creation and commercial viability of EV-based flexibility services. While EV aggregation can generate clear system benefits, transforming these benefits into sustainable revenue streams proved challenging under current economic conditions.

One of the key economic lessons learned is that aggregation alone is not sufficient to ensure profitability. Managing EV uncertainty, maintaining reliable service delivery, and integrating EVs into existing VPP operations require additional forecasting, monitoring, and operational effort. These activities increase operational costs for aggregators, while revenues from existing flexibility markets often remain limited, uncertain, or highly context dependent.

The demonstration also indicated that, under current conditions, local and DSO-oriented flexibility services may offer more promising economic opportunities than participation in wider wholesale or ancillary services markets. However, these opportunities are still highly dependent on regulatory support, defined procurement processes, and predictable remuneration schemes. Without long-term visibility on demand and pricing for flexibility services, investment signals for scaling EV-based solutions remain weak.

Overall, the economic lessons learned underline that improving the commercial viability of EV-based flexibility will require not only market design evolution, but also supportive regulatory frameworks and complementary value streams. These insights directly inform the subsequent assessment of service marketability presented in the following chapter.

In addition to the market and economic insights, the demonstrator resulted in the development of a substantial number of technical and operational innovations. Several of these innovations were

consolidated into KERs with clear potential for further exploitation beyond the project duration. For the Slovenian demonstrator specifically, the innovations include, among others, enhanced aggregation and forecasting functionalities within the VPP, advanced representative EV profiling methodologies, and upgraded DSO-oriented tools for flexibility forecasting and activation. These innovations reach high levels of technological and implementation readiness (TRL/IRL 8–9) and contribute directly to multiple KERs identified for the project, notably KER 15 and KER 17, which are both partially driven by the Slovenian use cases. As such, the demonstrator not only validated the feasibility of EV-based flexibility from a market perspective, but also generated concrete, exploitation-ready results that can support future commercial offerings, regulatory pilots, and large-scale deployments.

3.4.3 Long-Term Market Potential of EV-Based Flexibility Services

The Slovenian demonstrator suggests that the long-term market potential of EV-based flexibility services is substantial, particularly at the distribution level. As EV penetration increases and local grid constraints become more pronounced, DSOs are expected to seek cost-effective alternatives to traditional grid reinforcement. EV-based flexibility represents a scalable and adaptable solution to address these challenges.

At the same time, the demonstrator confirmed that market uptake is likely to be gradual rather than disruptive. Early commercial applications are expected to focus on controlled environments such as fleets, workplaces and residential communities with relatively predictable charging patterns. These niches provide an important stepping stone towards broader market integration.

The demonstrator confirms that the long-term market potential of EV-based flexibility services is substantial, particularly at the distribution network level. As EV penetration continues to increase, distribution grids are increasingly exposed to local congestion, peak demand and voltage management challenges. In this context, EV-based flexibility represents a scalable and cost-effective alternative to traditional grid reinforcement, allowing DSOs to actively manage demand growth while optimising existing infrastructure.

The demonstrator experience shows that the value of EV-based flexibility increases over time as the number of connected vehicles grows and as digital control capabilities improve. Unlike static infrastructure investments, flexibility services can adapt dynamically to changing grid conditions and usage patterns, making them particularly well suited to an energy system characterised by decentralisation and uncertainty. Over the long term, this adaptability supports both system efficiency and investment optimisation.

At the same time, the Slovenian demo clearly indicates that market uptake is likely to be gradual rather than disruptive. Early commercial applications are expected to focus on controlled and semi-controlled environments such as corporate fleets, workplaces and residential communities with relatively predictable charging behaviour. These niches provide a practical entry point for market deployment, enabling learning, trust building and refinement of operational processes before broader market integration is pursued. As regulatory frameworks mature and EV penetration increases further, these early applications are expected to evolve into more widespread adoption across diverse customer segments.

3.4.4 Competitive Positioning of EV-Based Services

In comparison with other flexibility options, EV-based services occupy a distinct position in the emerging flexibility landscape. Their primary competitive advantage lies in their distributed nature and their strong alignment with decarbonisation objectives. Electric vehicles are inherently mobile, widely dispersed and increasingly connected, enabling flexibility to be provided close to where grid constraints arise. This local availability differentiates EV-based flexibility from centralised solutions and enhances its relevance for distribution network operation. However, the demonstrator also highlights that EV-based services operate in a competitive environment. They face competition from stationary battery storage, demand response from other sectors and, in some cases, conventional grid reinforcement. Each of these options has specific strengths and limitations depending on local conditions, cost structures and regulatory treatment. The demonstrator indicates that EV-based flexibility is most competitive when evaluated on a system-wide cost-benefit basis and when combined with other flexible assets. Rather than positioning EV-based services as a standalone solution, their value is maximised when integrated into a broader portfolio that includes storage, demand response and network optimisation measures. This reinforces the importance of integrated planning approaches that consider multiple flexibility options simultaneously and select the most efficient combination for a given network context.

3.4.5 Transition from Pilot to Commercial Deployment

The transition from pilot-scale demonstrations to commercial deployment represents a critical phase for EV-based flexibility services. The Slovenian demonstrator illustrates that while pilot projects can accommodate a certain level of complexity, manual intervention and experimentation, commercial operation requires a fundamentally different approach. Reliability, predictability and scalability become dominant requirements once services are offered beyond a limited demonstration context. The demonstrator experience shows that commercial deployment necessitates streamlined operational processes, higher levels of automation and clearly defined roles and responsibilities among stakeholders. Systems must be designed to operate reliably under a wide range of conditions, with minimal manual oversight and robust fallback mechanisms. Accountability for performance, deviations and risks must be clearly allocated, both technically and contractually.

Another key insight concerns the importance of early and continuous alignment between technology providers, market actors and regulators. The demo confirms that early engagement with DSOs and regulatory authorities significantly reduces the risk of misalignment during later deployment stages. Such engagement helps ensure that technical solutions, market arrangements and regulatory expectations evolve in a coherent manner, facilitating a smoother transition from pilot projects to sustainable commercial services.

3.4.6 Implications for Future EV4EU Exploitation Activities

The insights gained from the demonstrator provide valuable and actionable input for future EV4EU exploitation activities. They support the development of exploitation strategies that are realistic, evidence-based and aligned with the gradual evolution of regulatory and market frameworks. Rather than assuming immediate large-scale deployment, the demonstrator experience highlights the importance of phased and adaptive exploitation pathways. The transition from pilot-scale demonstrations to commercial deployment represents a critical phase for EV-based flexibility services. The demonstrator illustrates that while pilot projects can accommodate a certain level of complexity,

manual intervention and experimentation, commercial operation requires a fundamentally different approach. Reliability, predictability and scalability become dominant requirements once services are offered beyond a limited demonstration context. The demonstrator experience shows that commercial deployment necessitates streamlined operational processes, higher levels of automation and clearly defined roles and responsibilities among stakeholders. Systems must be designed to operate reliably under a wide range of conditions, with minimal manual oversight and robust fallback mechanisms. Accountability for performance, deviations and risks must be clearly allocated, both technically and contractually. Another key insight concerns the importance of early and continuous alignment between technology providers, market actors and regulators. The demo confirms that early engagement with DSOs and regulatory authorities significantly reduces the risk of misalignment during later deployment stages. Such engagement helps ensure that technical solutions, market arrangements and regulatory expectations evolve in a coherent manner, facilitating a smoother transition from pilot projects to sustainable commercial services.

A central implication is that exploitation should build on mature and widely applicable solutions as a first step. V1G-based smart charging services offer a pragmatic entry point, as they are technically mature, require limited regulatory adjustments and already deliver tangible value to DSOs, aggregators and users. These services can generate early market traction while laying the foundation for more advanced offerings.

At the same time, the demonstrator confirms that V2X remains a strategically important long-term component of EV-based flexibility. Future exploitation activities should therefore continue to develop and test targeted V2X use cases in controlled environments, supported by regulatory sandboxes and close stakeholder collaboration. This approach enables continued innovation and learning while avoiding unrealistic market expectations.

Overall, the Slovenian demonstrator supports an exploitation strategy that is incremental, collaborative and resilient. By combining technological maturity, stakeholder engagement and regulatory alignment, the project results can be translated into sustainable market solutions that contribute meaningfully to the long-term transformation of the electricity and mobility systems.

3.5 Regulatory and Institutional Lessons Learned

The Slovenian demonstrator was implemented within a regulatory framework that is evolving to accommodate new flexibility providers and aggregation models. Lessons learned in this area highlight the influence of regulatory clarity, role definitions, and institutional responsibilities on the practical deployment of V2X solutions. The experience confirms that even when regulatory provisions formally allow certain activities, their practical implementation can still face institutional and procedural barriers. These insights underline the importance of regulatory harmonisation, clear role allocation between DSOs and aggregators, and early engagement with regulatory stakeholders.

The implementation of the Slovenian demonstrator provided a comprehensive perspective on the regulatory and institutional conditions influencing the deployment of EV-based flexibility and V2X solutions. While technical and operational capabilities reached a high level of maturity, the demonstration confirmed that regulatory frameworks and institutional readiness remain decisive factors in determining the pace and scope of real-world adoption. The lessons learned in this area highlight that regulatory evolution and institutional alignment must progress alongside technological development in order to enable scalable and sustainable deployment of V2X services.

3.5.1 Regulatory Lessons Learned

From a regulatory perspective, the Slovenian demonstrator confirmed that regulatory readiness currently lags technical capability. While both EU-level and national regulatory frameworks increasingly recognise the role of flexibility, aggregation, and active demand, specific provisions addressing V2X and bidirectional charging remain under development.

As a result, V2X solutions are currently best suited for pilot projects, demonstration activities, and regulatory sandbox environments, where controlled experimentation is possible. The lessons learned emphasise the importance of continued regulatory evolution to clarify roles, responsibilities, and remuneration mechanisms for V2X-based services. Without such developments, large-scale commercial deployment of bidirectional EV flexibility will remain limited, despite demonstrated technical feasibility.

From a regulatory perspective, the Slovenian demonstrator confirmed that existing EU-level and national energy policy frameworks increasingly recognise the role of flexibility, aggregation, and active demand participation. Slovenian legislation already provides a general legal basis for Virtual Power Plants and local flexibility markets, which enabled the demonstrator activities to be implemented without fundamental regulatory barriers. However, the experience also revealed that regulatory readiness for V2X still lags technical feasibility.

Specific regulatory provisions addressing bidirectional charging, V2X service participation, and remuneration models are not yet fully defined or harmonised. This creates uncertainty regarding eligible services, priority rules between market and grid activation, and long-term revenue perspectives for V2X-based flexibility. As a result, the demonstrator confirmed that V2X solutions are currently best suited for pilot projects, demonstration activities, and regulatory sandbox environments, where controlled experimentation is possible and deviations from standard market rules can be accommodated.

Another important lesson learned concerns the consistency of regulatory implementation across system levels. While aggregation and flexibility provision may be permitted in principle, differences in interpretation between national regulation, DSO practices, and market rules can create practical limitations. These inconsistencies increase investment risk and make it difficult for aggregators and technology providers to scale solutions beyond pilot deployments. The experience highlights that further regulatory clarification, particularly at the distribution level, is required to unlock the full potential of EV-based flexibility.

3.5.2 Lessons Learned on Regulatory Uncertainty and Risk Allocation

From a regulatory perspective, the demonstrator revealed that uncertainty remains a major barrier to the commercial deployment of EV-based flexibility services. Ambiguities related to asset classification, settlement rules, market access and responsibility for deviations create risk for market participants and discourage long-term investment. These uncertainties are particularly pronounced for advanced services involving bidirectional charging and participation in flexibility markets.

The demonstrator experience indicates that temporary regulatory arrangements, such as sandboxes and pilot exemptions, are effective tools for enabling innovation and learning under real-world conditions. However, such arrangements cannot replace the need for a stable and predictable long-term regulatory framework. Clear allocation of risks and responsibilities between aggregators, DSOs and end users is a prerequisite for scaling EV-based flexibility beyond pilot projects and ensuring investor confidence.

3.5.3 Institutional Lessons Learned

At the institutional level, the demonstrator demonstrated that successful deployment of EV-based flexibility relies heavily on effective coordination between organisations. Close collaboration between the DSO, the aggregator, technology providers, and research institutions was essential for translating regulatory principles into operational reality. Institutional readiness, including digital maturity, internal procedures, and decision-making processes, emerged as a critical enabling factor.

The demonstrator showed that institutional trust is built incrementally through transparent processes, clearly defined roles, and repeated successful operational interactions. DSOs, in particular, require confidence that flexibility activation will not compromise grid security and that aggregated resources will perform reliably. Clear communication channels and jointly agreed procedures significantly reduced operational risks and improved coordination between stakeholders.

Furthermore, the experience confirmed that institutional capacity-building is as important as regulatory evolution. Even where regulatory frameworks allow flexibility provision, limitations in organisational processes, data access, or internal coordination can slow down deployment. The lessons learned underline that regulatory progress must be accompanied by institutional alignment and continuous stakeholder engagement to ensure that V2X solutions can transition from demonstration environments into routine operational practice.

3.6 Data and Monitoring related Lessons Learned

The collection, processing, and analysis of data emerged as a critical aspect of the Slovenian demonstrator. Lessons learned include challenges related to data availability, temporal resolution, consistency across data sources, and alignment between operational data and KPI definitions. The demonstrator experience shows that data-related challenges can significantly influence both real-time operation and post-analysis of results. Reliable monitoring frameworks and well-aligned KPIs are therefore essential for evaluating the performance of flexibility services and for supporting evidence-based decision-making.

The Slovenian demonstrator underlined the central role of data availability, monitoring capabilities, and well-defined KPIs for the successful evaluation of EV-based flexibility solutions. While flexibility services rely on advanced control and coordination, their demonstrable value depends on the quality, consistency, and interpretability of underlying data. Lessons learned in this area highlight that data-related aspects should be treated as core design elements of demonstrators, rather than as supporting activities.

3.6.1 Data-Related Lessons Learned

One of the key lessons learned from the demonstrator concerns the availability, completeness, and consistency of data across multiple systems and stakeholders. Data were sourced from EV charging infrastructure, the VPP platform, DSO systems, secondary substations, and, in some cases, simulated environments such as BESS and aggregated EV profiles. Ensuring alignment across these heterogeneous data sources proved challenging, particularly with respect to data formats, temporal resolution, and synchronicity.

The demonstrator showed that missing or delayed data can significantly limit both real-time operation and post-event analysis of flexibility services. In several cases, the availability of market-related or activation-related data lagged system operation, requiring additional data pre-processing and manual

reconciliation. These lessons confirm that robust data governance, early definition of data flows, and harmonised data structures are essential prerequisites for large-scale deployment of EV-based flexibility solutions. A further key aspect will be the establishment of reliable communication with the vehicle itself and the ability to directly access data from EVs, which was not yet possible within the scope of the demonstrator.

3.6.2 Monitoring-Related Lessons Learned

Effective monitoring emerged as a critical enabling factor for both operational reliability and performance evaluation. The Slovenian demonstrator relied on continuous monitoring of charging stations, aggregated EV portfolios, BESS operation, and selected grid parameters. This enabled the detection of deviations between planned and actual behaviour, as well as validation of flexibility activation outcomes.

A key lesson learned is that monitoring systems must be designed to support both operational and analytical needs. While high-resolution data are valuable for technical validation, they also increase system complexity and data management requirements. The experience showed that insufficient monitoring granularity can mask important system dynamics, whereas excessive monitoring without clear purpose increases processing overhead. Balancing monitoring depth with usability and system performance was therefore identified as an important design consideration for future flexibility solutions.

3.7 KPI-Related Lessons Learned

The definition and calculation of KPIs proved essential for assessing the performance and impact of the Slovenian demonstrator. The demonstrator applied a structured KPI framework derived from Deliverable D7.1 [1], comprising 19 KPIs grouped across five categories: general descriptive, technical and ICT, service-related, environmental and social, and economic and market. The KPIs are mapped to the three Slovenian demonstration sites — Velenje, Krško and Ljubljana — according to their relevance, with 12 KPIs applicable to the BESS demonstrator in Velenje, 18 to the V2X charging station (CS) demonstrator in Krško and 10 to the Ljubljana site. One of the key lessons learned during the KPI evaluation is that KPI definitions must be closely aligned with available data and operational realities. Several KPIs required adaptation during the demonstration due to different data, evolving systems or differences between emulated and real-world operating conditions. The experience also highlighted the usefulness of dedicated KPI analysis tools, which enabled systematic aggregation, comparison and visualisation of results across multiple activations and use cases. Overall, the KPI-related lessons confirm that performance evaluation is an iterative process rather than a static exercise. Flexible KPI frameworks, combined with continuous stakeholder discussions and refinement, were found to be essential for generating meaningful insights and supporting evidence-based conclusions on the effectiveness of EV-based flexibility solutions.

Throughout the evaluation, KPI results are normalised with predefined targets (defined by stakeholder's expert group based on expert knowledge), where the achieved value is divided by the target value and capped at 1.0. This normalisation allows direct comparison across KPIs with different units and scales and provides a clear indication of whether the set targets have been reached. Values equal to 1.0 indicate that the target has been met or exceeded, while values below 1.0 indicate underperformance relative to the defined target. The interpretation follows a structured analytical logic: from general KPI performance overview, through identification of the most differentiating KPIs and to stakeholder-oriented evaluation.

The evaluation is structured separately for the two types of demonstrators in Slovenia: the BESS demonstrator in Velenje, where EVs were emulated using developed aggregated representative EV profiles (Section 3.7.1), and the V2X charging station demonstrators in Krško and Ljubljana, where real EVs, real V2X CSs, VPP management and the Local Market Platform were tested in operational conditions (Section 3.7.2). The KPI calculations for the BESS demonstrator in Velenje were performed as part of Deliverable D7.3 [2], where the results and initial observations were presented. In this section, the focus shifts to the calculation for the Krško and Ljubljana demonstrators and to the interpretation of results across all sites, with the aim of evaluating the demonstrator's performance from a stakeholder and marketability perspective.

3.7.1 Evaluation of BESS Demonstrator in Velenje

The BESS demonstrator in Velenje served as a controlled testing environment for the systematic evaluation of EV flexibility service provision. As described in D7.3 [2], 20 aggregated representative EV profiles were developed and validated to simulate realistic EV behaviour across five use cases (UCs): V1X and V2X at home (workday and weekend), V1X and V2X at work with employee's cars, and V1X and V2X at work with company EV fleet (workday and weekend). VPP activations of these EV profiles were performed for three individual flexibility services, local flexibility services, manual Frequency Restoration Reserve and automatic Frequency Restoration Reserve (mFRR and aFRR), as well as for the combined participation in all three services simultaneously. In total, 12 out of 19 Slovenian KPIs are relevant for the Velenje demonstration site, as defined in D7.1 [1]. Table 5 in D7.3 [2] presents the average KPI values calculated across 20 aggregated representative EV profiles activated on the BESS demonstrator.

To evaluate the performance of the BESS demonstrator across different UC and service configurations, radar charts were constructed for each of the four service types: local flexibility services, mFRR, aFRR, and the combination of all three services. The radar charts display normalised KPI values for all five UCs simultaneously, enabling direct visual comparison of performance patterns, presented on Figure 5.

The general evaluation across the four radar charts reveals several consistent patterns. A large share of technical and operational KPIs, such as demonstrator accuracy (KPI 1), BESS technical operation (KPI 17), and aggregator activation success (KPI 18), reach or are very close to the target value, confirming stable technical feasibility across all services and UC configurations. Environmental and system-related KPIs, including CO₂ reduction (KPI 6) and forecast accuracy (KPI 9, KPI 10), are largely achieved in most configurations, indicating that baseline sustainability objectives are met regardless of the service type. Cost reduction for DSO (KPI 4) remains consistently limited across all configurations, which was expected given that this is a single demonstrator at one location and its flexibility contribution compared to actual DSO needs across the whole distribution grid is inherently small.

The main performance differentiation between UCs and services does not arise from technical feasibility, but from three KPIs that show the strongest dispersion across configurations: V2G success level (KPI 2), Profit for aggregator (KPI 3) and Increased flexibility for grid (KPI 14). These KPIs were selected because they capture the perspectives of the three main stakeholders involved in the Slovenian demonstrator: the DSO (represented by flexibility provided to the grid), the Aggregator (represented by flexibility and profit potential), and the joint system value (represented by V2G utilisation success).

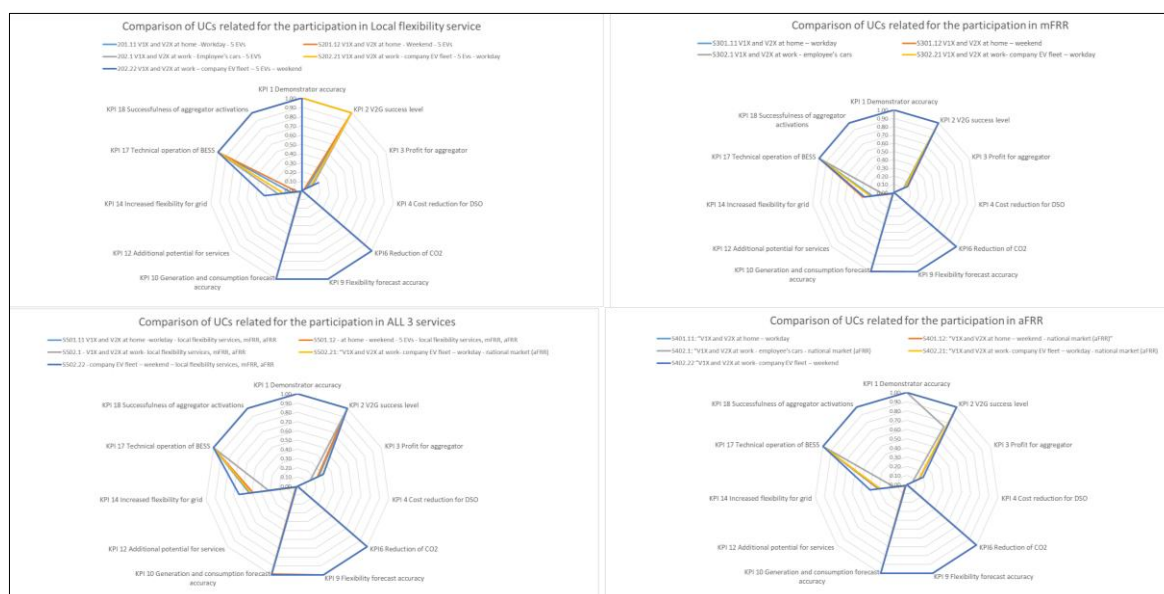


Figure 5: Comparison of KPIs performance across five use cases for different service configurations: Local Flexibility, mFRR, aFRR, and combined participation in all three services. The values are normalised with predefined targets.

A consistent set of findings emerges across all four service configurations. Fleet based UCs, in particular the company EV fleet during weekends, deliver the highest flexibility volumes and corresponding profit potential across all services, while homebased UCs provide stable but smaller contributions. The employee-based UC underperforms structurally in balancing markets (mFRR and aFRR) due to lower service needs during connection period and limited V2G utilization, although it remains adequate for local flexibility services. V2G utilization is high in 4 out of 5 UCs across all service configurations, confirming that V2G has significant potential when combined with EV based flexibility provision. Combined participation in local flexibility, mFRR and aFRR simultaneously produces the strongest results across all UCs and reduces performance dispersion across services. Multiservice integration therefore emerges as the potentially most scalable and stakeholder aligned participation model for V2X based flexibility.

3.7.2 Evaluation of V2X CSs demonstrators in Krško and Ljubljana

While the BESS demonstrator in Velenje enabled systematic testing through emulated V2G EV profiles, the V2X CS demonstrators in Krško and Ljubljana represent the real-world deployment of V2X technology in the Slovenian demonstrator. At these sites, prototype V2X CSs were installed, connected to GEN-I's VPP platform, and integrated with Elektro Celje's ADMS, Local Market Platform (FlexIS), and EVT platform. The testing covered the complete operational chain, from DSO-triggered activation signals through the market platform, to VPP dispatch and actual V2X charging and discharging of EVs at the CSs.

The evaluation presented is based on the tests performed during the demonstration period, which covered both the validation of individual technical components and the demonstration of the Slovenian use cases (UC9 through UC12) as defined in D7.1 [1]. Unlike the BESS demonstrator, where 20 aggregated representative EV profiles were tested in a controlled environment, the V2X CS demonstrators reflect the variability, challenges, and constraints of real-world V2X operation — including EV-charger compatibility, communication reliability, and actual employee's user behaviour.

Based on this, the evaluation of the V2X CS demonstrators receives particular attention in this deliverable, as it provides the most direct evidence for the marketability and scalability assessment of the proposed V2X flexibility services.

The performed tests are structured into three groups based on their scope and purpose:

- VPP and CS tests: These include all VPP-managed activations performed directly through the CSMS at the Krško and Ljubljana demonstration sites. This group covers 44 positive and 51 negative activations and represents the core flexibility testing, where the VPP dispatched power setpoints to the V2X CSs and measured the response of connected EVs. These tests validate the operational performance of the VPP–CS–EV chain without the market platform layer.
- Platform, VPP, and CS tests: These represent the full end-to-end demonstration of the Slovenian UCs, where flexibility was procured and activated through the Local Market Platform (FlexIS). In this configuration, the DSO's ADMS detected a grid constraint, the Lambda platform generated a signal, the FlexIS platform published a flexibility tender, the Aggregator submitted bids through the trading platform, and upon acceptance, the VPP activated the requested flexibility at the CSs. This group includes 3 negative and 4 positive activations. These tests are particularly important because they validate the complete communication and market chain from DSO to EV, including all platform interfaces and market processes.
- CS tests: These represent 195 charging sessions collected from GEN-I employees who used the V2X CSs for regular workplace charging. These sessions capture actual EV user behaviour without flexibility activation and provide a baseline for evaluating charging patterns, occupancy, and the potential for smart charging (V1G) flexibility.

Table 1 provides a summary of the testing performed across the Slovenian V2X CS demonstrators, including the total number of tests and the volumes of activated flexibility.

Table 1: Summary of testing performed at V2X CS demonstrators in Krško and Ljubljana

	Total values
Number of test	327
Number of charging tests	72 (+195*)
Number of discharging tests	60
Total activated negative flex (energy) [kWh]	622.25
Total activated positive flex (energy) [kWh]	218.33
Total testing hours [h]	1885.7
Average testing period	9h

*Number of charging sessions from CS tests

In total, 327 tests were performed across the Slovenian V2X CS demonstrators including 102 V2X activations for UC demonstration purposes (95 tests of VPP and CS tests, 7 tests of Platform, VPP, and CS tests) and 195 charging sessions collected from regular EV usage by GEN-I employees at the Ljubljana demonstration site. The remaining 30 tests focused on the technical evaluation of individual components (CSs, VPP, and EVs) and are not included in the KPI evaluation but contribute to the total

testing volumes reported in Table 1. Both V1G and V2G modes were successfully demonstrated at the Slovenian sites under real-world conditions. KPI results for the three test groups relevant for KPI evaluation are presented separately in Table 2. As defined in D7.1 [1], 18 out of 19 Slovenian KPIs are relevant for the Krško demonstration site, while 10 KPIs are relevant for the Ljubljana site — KPIs that are not applicable for selected groups and cannot be computed due to lack of required data, are marked with grey cells.

Table 2: KPI results related to the testing of Local market platform, VPP and V2X CSs at Krško and Ljubljana demonstration sites

KPI	Name of KPI	Target	Unit	VPP* and CS tests (44 positive activations, 51 negative activations)	Platform*, VPP and CS tests (3 positive and 4 negative activations)	CS tests (195 sessions)
KPI 1	Demonstrator accuracy	50	%	77.612	82.446	100.000
KPI 2	V2G success level	15	%	57.60	42.32	
KPI 3	Profit for aggregator	50	€/CS	2.40	1.83	
KPI 4	Cost reduction for DSO	5	%	0.00	0.00140	
KPI 5	User satisfaction	50	%	80.00	80.00	80
KPI 6	Reduction of CO2	6	kg/day	31.75	36.54	34.47
KPI 7	Technical operation of CS	97	%	99.90	99.90	99.9
KPI 8	Data reliability	95	%	100.00	100.00	100
KPI 9	Flexibility forecast accuracy	50	%	92/100**	92	92
KPI 10	Generation and consumption forecast accuracy	50	%		79.00	
KPI 11	Voltage compliance	100	%		100.00	
KPI 12	Additional potential for services	20	%	18.83	18.07	5.86/per session
KPI 13	Occupancy of the charging station	2	h/day	7.80	3.31	8h* (12%***)
KPI 14	Increased flexibility for grid	35	%	3.48	2.64	
KPI 15	Flexibility from EV availability	35	%	100.00	100.00	100
KPI 16	Request fulfilment ratio of flexibility by DSO	70	%		100.00	
KPI 17	Technical operation of BESS	97	%			
KPI 18	Successfulness of aggregator activations	70	%	93.48	97.00	
KPI 19	Aggregators bidding performance	100	%		100.00	

*Disclaimers: * Ljubljana, **Krško, ***Based on average CS session duration in a day*

The KPI results presented in Table 2 reveal several important patterns that characterise the performance of the V2X CS demonstrators.

Across all three test groups, technical and operational KPIs consistently meet or exceed their targets. Technical operation of charging stations (KPI 7) reaches 99.9% in all configurations and data reliability (KPI 8) reaches 100%, indicating that the data exchange procedures between CSs, the VPP and the market platform operated without failures. Flexibility from EV availability (KPI 15) reaches 100% in all groups, successfulness of aggregator activations (KPI 18) stands at 93.48% and 97.00% (well above the 70% target), and demonstrator accuracy (KPI 1) ranges from 77.6% to 100%. These results confirm that the technical operation and interoperability of the demonstrator's components — from CS hardware, through VPP management, to market platform integration — are not a limiting factor for the direct deployment of V2X flexibility services.

Figure 6 presents a comparative overview of normalised KPI performance for the VPP and CS tests (left) and Platform, VPP and CS tests (right), where the patterns described in the following text can be visually observed.

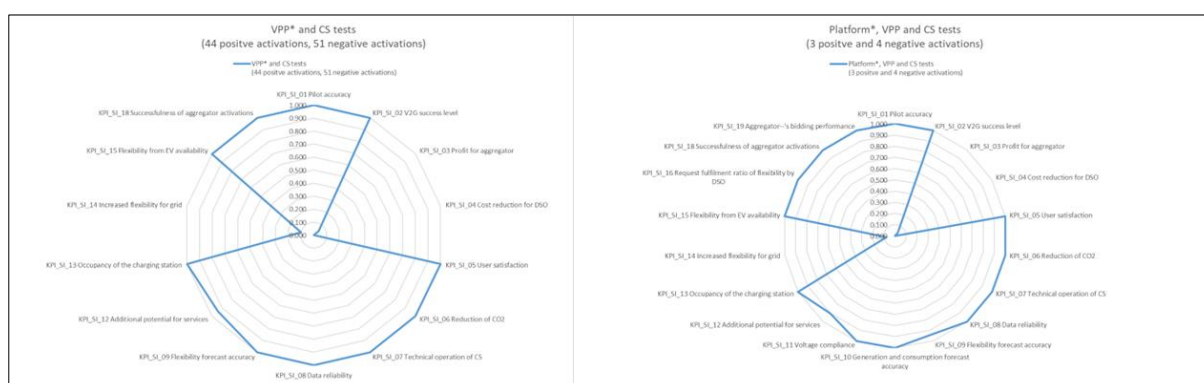


Figure 6: Comparison of normalised KPI performance for VPP and CS tests (left) and Platform, VPP and CS tests (right). The values are normalised with predefined targets.

V2G success level (KPI 2) reaches 57.60% in VPP and CS tests and 42.32% in Platform tests, both significantly exceeding the 15% target. These values indicate that a substantial share of the total flexibility provided during the tests was enabled specifically through bidirectional V2G operation, rather than through smart charging (V1G) alone. Simulation tool V2GFlex developed within Slovenian demonstrator simulates the Krško location from the flexibility potential perspective [15].

The added value of V2X over V1G is further confirmed by the comparison of flexibility volumes for the same UC (employees' EVs): V1G alone provides approximately 40 kWh of flexibility per session, whereas the corresponding aggregated representative EV profile with V2X delivers 32–35 kWh for individual balancing services, 64 kWh for local flexibility services, and up to 77.5 kWh under combined participation in all three services. V2X therefore increases the flexibility potential of EVs for service participation compared to V1G, with the actual gain depending on the targeted services and their activation patterns.

Connected EVs retain meaningful untapped flexibility capacity beyond what is activated. Additional flexibility potential (KPI 12) reaches 18.83% and 18.07% across the two activation-based test groups and 5.86% per CS session. While occupancy of the charging station (KPI 13) reaches 7.80 hours per day for VPP and CS tests and 3.31 hours per day for platform tests, both above the 2 h/day target and approximately 8 h/day for CS tests, all well above the 2 h/day target. These occupancy and additional-potential values define the time windows during which EVs are realistically available for

flexibility services and indicate room for increased utilisation if market conditions and user agreements allow.

Economic and market-related KPIs remain below their targets across all test groups. Profit for aggregator (KPI 3) does not reach the targeted value in both VPP and CS tests and Platform tests. Cost reduction for DSO (KPI 4) is low, while increased flexibility for grid (KPI 14) remains below the set target. These results indicate that the demonstrator does not yet deliver meaningful economic impact when assessed against its defined performance targets, based on expert knowledge. However, these economic results must be interpreted in the context of the demonstrator's scale. The V2X CS demonstrators in Krško and Ljubljana comprise a small number of CSs at two locations, providing flexibility from a limited number of connected EVs. When measured against the overall system-level flexibility needs of the DSO (Elektro Celje), the absolute contribution of the demonstrator is inherently small. The low economic KPI values therefore do not indicate a fundamental limitation of the V2X business model but rather reflect the difference between demo-scale testing and system-scale deployment. The technical performance confirms that the components and processes work reliably; translating this into meaningful economic value requires large-scale deployment with a substantially larger number of V2X CSs and EVs distributed across the distribution grid.

Generation and consumption forecast accuracy (KPI 10), available only for Platform tests, reaches 79.00%, exceeding the 50% target. This KPI measures the accuracy of forecasts for the secondary substation load, which is a key input for the DSO's grid management and flexibility procurement decisions. Flexibility forecast accuracy (KPI 9) reaches 100% for Krško and 92% for Ljubljana (VPP and CS tests), and 100% for Platform tests, also well above the 50% target. In general, EV user behaviour remains inherently difficult to predict, and V2X technology is still in development, which limits the precision of flexibility potential estimations. Nevertheless, both forecast KPIs substantially exceed their targets, confirming that the forecasting tools developed within the project are fit for purpose.

The Platform, VPP and CS tests are particularly important because they validate the full end-to-end market chain. KPIs measurable only in this test group, voltage compliance (KPI 11), request fulfilment ratio of flexibility by DSO (KPI 16) and aggregators bidding performance (KPI 19), all reach 100%, confirming that flexibility activations did not cause voltage violations, that all DSO requests issued through the Local Market Platform were fulfilled, and that all bids submitted. Due to the insufficient regulatory framework in Slovenia for local flexibility market (LFM) operation, market processes were emulated rather than executed on the actual energy market; however, the successful execution of the complete market chain, from tender publication, through bid submission and selection, to activation and fulfilment verification, confirms the technical and procedural readiness of the local flexibility market framework for actual market deployment, once the regulatory conditions are in place.

3.8 Stakeholder and User-Related Lessons Learned

The Slovenian demonstrator highlighted the critical importance of stakeholder collaboration and user-centric design for the successful deployment of EV-based flexibility solutions. Lessons learned in this area extend beyond technical performance and underline that flexibility services are inherently socio-technical solutions, relying on the coordinated interaction of multiple actors as well as on user acceptance and trust. The experience confirmed that minimising active user involvement while maintaining transparency, predictability, and clear value propositions is a key success factor. Equally, effective stakeholder communication and well-defined expectations proved to be as important as the underlying technical implementation for the overall success of the demonstrator.

3.8.1 EV User Perspective

User acceptance emerged as a critical success factor for the deployment of EV-based flexibility solutions. The demonstrator experience showed that unidirectional smart charging (V1G) is generally perceived by users as non-intrusive, as it does not affect driving behaviour, charging convenience, or battery usage in a noticeable way. As such, V1G represents a low-barrier entry point for engaging EV users in flexibility services and for building initial trust in managed charging solutions.

In contrast, V2X solutions introduce additional user concerns, particularly regarding battery degradation, mobility availability, and the overall level of control transferred to external actors. The lessons learned indicate that successful V2X deployment requires clearly defined incentives, transparent communication, and explicit safeguards ensuring that user mobility needs are always prioritised over system or market objectives. Users must retain confidence that charging and discharging actions will not negatively affect their daily usage patterns or long-term vehicle value.

The demonstrator also showed that simplicity and predictability are essential for long-term acceptance. Excessive configuration options or complex user interactions can create uncertainty and reduce willingness to participate. These lessons suggest that V2X services should be designed to operate largely in the background, with clear opt-in/opt-out mechanisms, intuitive information provision, and measurable benefits communicated to users in an accessible manner. Without these elements, sustained participation in bidirectional charging services is likely to remain limited.

User behaviour emerged as one of the most influential factors affecting the practical flexibility potential of EVs. The Slovenian demonstrator confirmed that EV users are generally willing to participate in smart charging schemes when impacts on mobility are minimal, clearly communicated and predictable. Acceptance of V2X services, however, proved to be more sensitive and strongly dependent on trust, perceived fairness and transparency. A key lesson learned is that financial incentives alone are not sufficient to ensure sustained participation. Users also value simplicity, predictability and a sense of control over their assets. Providing clear information about expected impacts, offering intuitive interfaces and ensuring easy opt-out options significantly increase acceptance and reduces operational uncertainty. Behavioural aspects must therefore be considered as an integral part of service design rather than as an afterthought. Slovenian demonstrator clearly demonstrated that effective cooperation among stakeholders is essential for the successful implementation of EV-based flexibility solutions. Close collaboration between DSOs, aggregators, OEMs, charging infrastructure providers, and research partners was required throughout all phases of the demonstration, from system design and integration to operation and evaluation. One of the key lessons learned is that early and continuous stakeholder engagement significantly reduces implementation risks, particularly with respect to system integration, operational coordination, and interpretation of regulatory requirements. Establishing a shared understanding of objectives, constraints, and responsibilities at an early stage proved to be a decisive factor for overcoming both technical and organisational barriers. The experience also highlighted that stakeholder alignment is not a one-time activity, but an ongoing process that must adapt as technologies, regulations, and operational practices evolve. Regular coordination, transparent communication, and structured decision-making mechanisms supported trust building and enabled efficient problem resolution during the demonstration. These findings underline that successful EV-based flexibility deployment depends as much on governance and cooperation models as on technical solutions themselves.

3.9 Replicability and Scalability Lessons Learned

The Slovenian demonstrator confirmed that the core concepts of EV-based flexibility, aggregation, and coordinated control through a VPP are replicable beyond the specific pilot context. The demonstrated use cases and system architectures are not inherently site-specific and can, in principle, be transferred to other regions and electricity systems. However, the experience clearly showed that scalability is not driven by technology alone but strongly depends on a set of local boundary conditions.

Key factors influencing replicability and scalability include EV penetration levels, regulatory openness to aggregation and flexibility services, availability of V2X-capable vehicles and charging infrastructure, and the digital maturity of DSOs and aggregators. In addition, the ability to establish reliable communication with vehicles and to access vehicle-generated data will be a critical enabler, not only for system operation but also for effective interaction with end users. In contexts where EV penetration is still low or where DSOs lack advanced monitoring and digital control capabilities, the immediate system-level impact of EV-based flexibility remains limited. Similarly, insufficient regulatory clarity or misalignment between market and grid processes can significantly slow down the replication of demonstrated solutions.

The lessons learned strongly suggest that a phased deployment approach represents the most realistic and robust pathway towards large-scale adoption. Starting with unidirectional smart charging (V1G) allows stakeholders to gain operational experience, validate aggregation and forecasting methods, and build trust among DSOs, aggregators, and users. This initial phase also enables gradual adaptation of market practices and institutional processes without exposing the system to high complexity or risk.

Based on the Slovenian experience, V2X solutions are best introduced in a second phase, once sufficient technical maturity, user acceptance, and regulatory clarity have been achieved. At this stage, bidirectional charging can deliver additional system value, particularly for grid-oriented and local flexibility services, but only when supported by stable operational frameworks and clearly defined safeguards for users. The transition from V1G to V2X should therefore be viewed as an evolutionary step rather than a disruptive leap.

Overall, the Slovenian demonstrator identified an incremental and modular scaling strategy as the most effective way to move from pilot demonstrations toward broader market adoption. This approach reduces deployment risk, allows adaptation to local conditions, and increases the likelihood that EV-based flexibility solutions can be sustainably replicated across different regions and electricity systems.

3.9.1 Cross-Demo Comparability and Knowledge Transfer

An important outcome of the Slovenian demonstrator is its contribution to cross-demonstrator learning within the EV4EU project. While each demonstrator operates within a distinct regulatory, technical and market context, many challenges related to EV availability, V2X CS availability, system integration and stakeholder coordination are shared across countries.

The lessons learned indicate that systematic comparison of demonstrators is highly valuable for distinguishing between context-specific issues and structural challenges that are likely to arise in any EV-based flexibility deployment. This insight supports the development of more generalised guidelines and best practices, facilitating knowledge transfer and accelerating future deployments across Europe.

3.10 Summary of Lessons Learned from the Slovenian Demonstrator

The Slovenian demonstrator provided a comprehensive set of lessons learned covering technical, operational, market, regulatory, data-related, and human aspects of EV-based flexibility deployment. The results confirmed that EV aggregation and smart charging concepts are technically feasible and operationally viable, but their successful transition from pilot demonstrations to large-scale deployment depends on a balanced co-evolution of technology, regulation, market design, data availability, and stakeholder readiness.

From a technical and system perspective, EV-based flexibility was shown to be fundamentally different from conventional stationary resources. Uncertainty related to EV availability, user behaviour, and charging patterns requires dedicated forecasting, monitoring, and control strategies. While VPPs can successfully integrate EVs into aggregated portfolios, mechanisms for managing uncertainty and prioritising use cases are essential to ensure reliable service delivery.

At the operational level, the demonstrator highlighted that flexibility provision is not only a technical challenge but also an organisational one. Clear operational procedures, fallback strategies, and continuous coordination between aggregators, DSOs, and technology providers were identified as key enablers for stable operation. The execution of multiple use cases in parallel further emphasised the need for prioritisation mechanisms and modular system design.

The market and economic lessons learned revealed that current electricity and flexibility markets are not yet fully adapted to the characteristics of EV-based resources. Aggregation enables participation, but minimum bid sizes, product definitions, and settlement rules often limit efficient monetisation. From an economic point of view, EV flexibility creates system value, but sustainable business cases remain highly dependent on market design and regulatory support, especially at the distribution level.

In terms of regulatory and institutional aspects, the demonstrator confirmed that regulatory readiness lags behind technical capabilities. While aggregation and flexibility are increasingly recognised in legislation, specific provisions for V2X remain under development. Institutional readiness, including digital maturity and internal coordination of DSOs and aggregators, proved to be equally important. Regulatory progress must therefore be accompanied by institutional capacity-building and stakeholder alignment.

Strong lessons were also learned regarding data, monitoring, and KPIs. Reliable, synchronised, and well-structured data emerged as a prerequisite for both operational control and performance evaluation. Monitoring systems need to support real-time operation as well as post-analysis, while KPI frameworks must remain flexible and aligned with available data. Performance evaluation was confirmed to be an iterative process rather than a one-off exercise.

Finally, the demonstrator underlined the importance of stakeholder cooperation and user acceptance. EV users are more willing to participate in non-intrusive solutions such as V1G, while V2X requires clear incentives, transparency, and strong safeguards to protect mobility needs. Effective stakeholder collaboration, based on early engagement and continuous coordination, was identified as a decisive success factor across all phases of the demonstration.

Overall, the Slovenian demonstrator demonstrated that EV-based flexibility is best deployed through an incremental and phased approach, starting with V1G and gradually introducing V2X as technical maturity, regulatory clarity, and user trust increase. This approach was identified as a low-risk and replicable pathway towards scalable market deployment across different regional contexts.

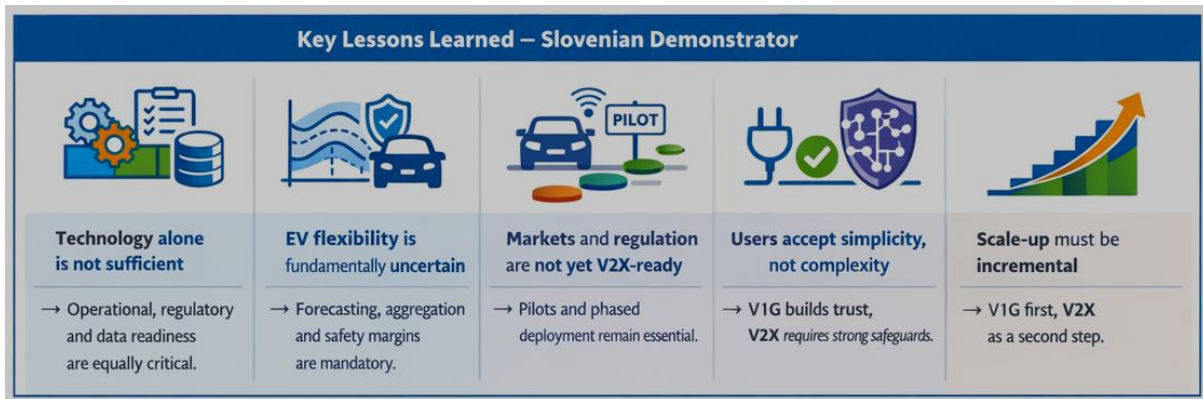


Figure 7: Key Lessons Learned from Slovenian Demonstrator

4 PART II – SERVICES MARKETABILITY ASSESSMENT

The Slovenian demonstrator validated a comprehensive portfolio of services based on the aggregation of EV-based flexibility within a VPP. The services were implemented across three locations, Ljubljana, Velenje and Krško, and were designed to respond to both system-level requirements and local distribution grid challenges. Particular emphasis was placed on the distribution network level, where increasing electrification is already creating tangible operational constraints.

The proposed solutions integrate flexibility from electric vehicles with complementary assets and advanced digital platforms. These platforms enable key functionalities such as forecasting of consumption and availability, aggregation of distributed resources, activation of flexibility services, and continuous performance monitoring. The demonstrator confirmed that the technical components supporting these services have reached high levels of maturity, with several core solutions achieving TRLs between 7 and 9. In parallel, the associated service concepts and business models progressed to Innovation Readiness Levels (IRLs) between 7 and 8, indicating that the solutions go beyond experimental testing and are approaching pre-commercial applicability.

A key characteristic of the demonstrated services is their modular architecture. This allows individual service components to be deployed, adapted or scaled depending on local regulatory conditions and market structures. Such flexibility is essential for future commercial deployment, as it enables replication of the Slovenian solutions in other regions without requiring fundamental redesign.

4.1 Market Context and Target Customers

The market context for EV-based flexibility services is shaped by the rapid electrification of transport and the increasing pressure this places on electricity distribution networks. Across Europe, DSOs are facing growing challenges related to local congestion, voltage management and the integration of new loads, particularly as electric vehicle adoption accelerates. According to EU-level assessments, distribution grids are expected to integrate up to 30 million electric vehicles by 2030, making flexibility solutions a critical enabler for maintaining system reliability while avoiding excessive grid reinforcement costs. [16]

This trend is already visible in Slovenia, where electric vehicle uptake and charging infrastructure deployment are progressing rapidly, especially in urban areas such as Ljubljana. [17] While the expansion of public and private charging infrastructure improves accessibility and supports EV adoption, it also increases the need for smarter and more coordinated grid operation. EV-based flexibility therefore emerges as a strategic response to both market growth and infrastructure constraints, enabling DSOs and aggregators to manage increasing demand in a cost-effective and scalable manner.

Within this context, the Slovenian demonstrator was designed to reflect realistic market conditions and stakeholder interactions. By focusing on distribution-level services and engaging key actors such as DSOs, aggregators and EV users, the demonstrator provides valuable insight into which customer segments are most likely to adopt EV-based flexibility services in the near to medium term, and under which conditions such services can deliver tangible system and market value.

4.1.1 Target Markets and Customer Segments

The primary target customers for the services demonstrated in the Slovenian demo are DSOs. DSOs are increasingly confronted with local grid congestion caused by the rapid growth of electric vehicle charging and electrification of heating. In this context, EV-based flexibility offers a viable non-wire alternative to conventional grid reinforcement, particularly in areas with high or rapidly growing EV penetration. Beyond DSOs, aggregators and VPP operators represent a key customer segment. These actors can leverage EV-based flexibility to expand their service portfolios and increase operational resilience by diversifying the types of assets under management. Municipalities and local energy communities also constitute an important emerging market, especially where there is interest in local energy optimisation, smart mobility and sustainable urban development. In the medium to long term, TSOs may benefit indirectly from aggregated EV flexibility through improved coordination with DSOs and more efficient system-wide balancing.

A critical stakeholder group underpinning the viability of these services are EV drivers and vehicle owners. Their active participation is essential to ensure sufficient flexibility capacity, as they ultimately provide the controllable assets (vehicles and batteries). For these users, participation in flexibility schemes represents a tangible value proposition, either through additional revenue streams or reduced charging costs, thereby incentivising engagement and enabling scalable deployment of EV-based flexibility solutions.

4.1.1.1 EV Market Outlook – Key Forecasts (EU and Slovenia)

Available forecasts consistently indicate that the European electric vehicle market will continue to grow rapidly towards 2030, driven primarily by tightening CO₂ emission regulations, the Fit for 55 package and the planned phase-out of internal combustion engine (ICE) vehicle sales by 2035. According to S&P Global Mobility, battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) are projected to account for just under three-quarters of new passenger car sales in the EU by 2030, while the share of conventional internal combustion engine vehicles is expected to decline to marginal levels [18].

From a market value perspective, multiple industry analyses confirm strong growth dynamics. For example, Global Market Insights and Fortune Business Insights project sustained double-digit compound annual growth rates for the European EV market up to and beyond 2030, supported by expanding charging infrastructure, declining battery costs and increasing model availability. These trends indicate that EVs will move from early-adopter segments into the mass market during the current decade [19], [20].

From a system perspective, this growth implies a substantial increase in EV charging demand and a corresponding rise in flexibility potential at distribution level, reinforcing the relevance of EV-based flexibility solutions such as those demonstrated in EV4EU.

In Slovenia, EV adoption is progressing at a smaller scale but broadly in line with European policy objectives. According to the European Alternative Fuels Observatory and the assessment of the Slovenian National Policy Framework, electric passenger cars are expected to represent approximately 16.9% of the total passenger car fleet by 2030. This represents a significant increase compared to the early 2020s and reflects ongoing support measures, including purchase incentives and continued expansion of charging infrastructure [21].

While Slovenia is not expected to reach the same penetration levels as leading EU markets by 2030, its relatively dense charging infrastructure and compact grid make it particularly suitable for early

deployment of smart charging and flexibility solutions. As EV numbers grow, local grid impacts are expected to become more pronounced, especially in urban and semi-urban areas, increasing the relevance of EV-based flexibility services for DSOs.

The figure below provides a high-level comparison between the projected EV penetration in the EU and Slovenia by 2030, based on publicly available forecasts. It highlights the difference between EU-level sales shares and national fleet shares, which is important when interpreting market readiness and flexibility potential [21].

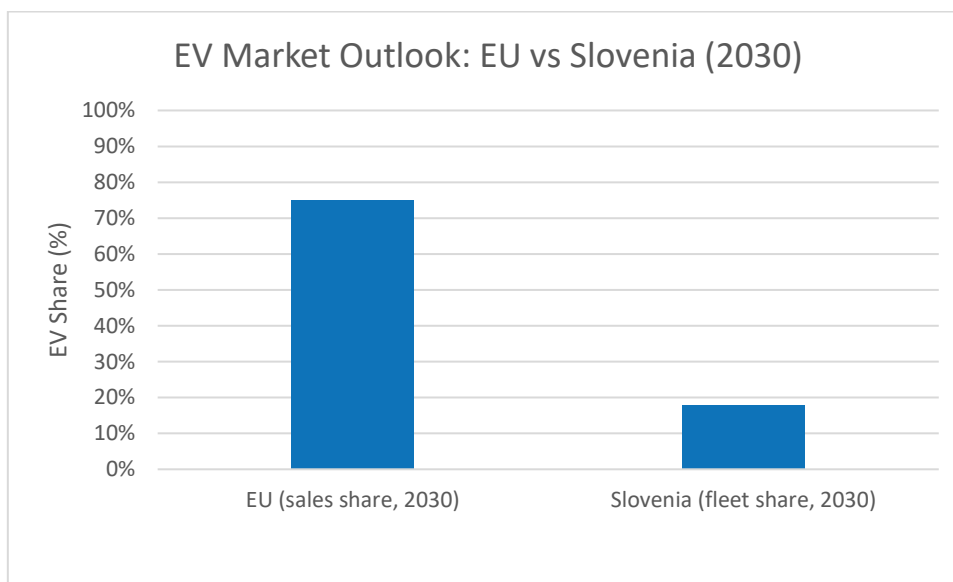


Figure 8: EV Market Outlook: EU vs Slovenia (2030) [22]

In Figure 8, values refer to the projected share of EVs in new passenger car sales, while the Slovenian value refers to the projected share of EVs in the total passenger car fleet [18], [23].

These forecasts confirm that the growth of the EV market will be strong but uneven across Europe. At EU level, rapid growth in new EV sales will quickly increase the available flexibility potential, particularly in countries with high adoption rates. In Slovenia, growth will be more gradual, but still sufficient to justify early deployment of smart charging (V1G) and targeted V2X solutions in controlled environments.

In addition to regulatory and market developments, targeted incentives will play a crucial role in enabling the deployment of V2X solutions and the rollout of V2X-enabled charging infrastructure (CS V2X). The development of such solutions requires significant upfront investments in infrastructure, digital systems, and operational capabilities, which can present a barrier without adequate policy support. Alongside incentives for the deployment and upgrade of charging infrastructure, it is equally important to maintain and strengthen incentives for the uptake of electric vehicles. A sufficient penetration of EVs is a fundamental prerequisite for unlocking the flexibility potential of V2X, as vehicles themselves constitute the core resource. Therefore, a coordinated approach combining financial incentives, regulatory measures, and user-focused support schemes will be essential to accelerate the development of the V2X ecosystem and enable large-scale flexibility provision at the distribution grid level.

This reinforces the conclusions of the Slovenian demonstrator: EV-based flexibility should be deployed through a phased approach, aligned with market maturity and EV penetration, starting with V1G and gradually expanding towards V2X as both technology and regulatory conditions mature.

4.1.1.2 Flexibility Market – EU Context and Current State

At EU level, the flexibility market refers to the set of mechanisms, products and procurement processes through which electricity systems access the ability to adjust generation or consumption in response to system and grid needs. According to ACER, flexibility enables demand response, storage and flexible generation to balance supply and demand, manage grid constraints and integrate renewable energy in a cost-effective manner. [24]

Flexibility is increasingly differentiated into:

- System flexibility, mainly related to balancing and adequacy at TSO level, and
- Network (distribution) flexibility, aimed at addressing local congestion, voltage issues and grid availability at DSO level.

This distinction has been formally reinforced by the EU Electricity Market Design reform (2024) and the associated national flexibility needs assessment methodology developed by ENTSO-E and the EU DSO Entity and approved by ACER in 2025 [25].

The most dynamic development currently takes place at distribution level, where DSOs are increasingly expected to procure flexibility as an alternative or complement to grid reinforcement. The EU DSO Entity – Report on Distributed Flexibility Practices (2026) confirms that markets for local services are emerging across Europe but remain heterogeneous and strongly dependent on national regulatory frameworks [16].

According to Eurelectric, DSOs in EU Member States typically access flexibility through a combination of four mechanisms:

- rule-based approaches embedded in grid connection and operation,
- network tariffs (e.g., time-of-use signals),
- flexible connection agreements, and
- market-based procurement of flexibility services. [26]

The flexibility market in Europe is economically significant but structurally emerging. Rather than constituting a single, liquid market with uniform price signals, flexibility is currently realised through a combination of regulatory mechanisms, local procurement schemes and pilot-based market arrangements, with a strong emphasis on distribution-level needs. Within this evolving framework, EV-based flexibility is well positioned, particularly when delivered through aggregation and targeted local services.

At EU level, the flexibility market does not yet exist as a single, unified market with a clearly defined total monetary size. This is explicitly acknowledged by multiple authoritative sources, including ACER [24], the EU DSO Entity [27] and Eurelectric [26]. Instead, flexibility is procured through a variety of mechanisms spanning balancing markets, congestion management solutions, network tariffs, pilot local flexibility markets and bilateral contractual arrangements. As a result, what can be meaningfully quantified today is not the overall market value, but rather the system relevance of flexibility and the direction of procurement trends.

Evidence from EU-level monitoring confirms this transitional character. The JRC DSO Observatory 2024 [28] indicates that only around 15% of EU Member States currently provide explicit regulatory incentives for flexibility, despite rapidly increasing needs at distribution level. At the same time, more than half of European DSOs are already involved in flexibility pilots or experimental schemes, signalling

a gradual shift from exploratory projects towards more structured procurement approaches. Complementing this view, the smartEn Market Monitor for Demand Side Flexibility shows that demand-side flexibility resources, including electric vehicles, are technically available in most EU countries, while commercial participation remains constrained primarily by regulatory and market design barriers rather than by asset availability [29].

Against this background, EU institutions deliberately avoid presenting the flexibility market as a standalone commodity market with a single “€ value”. Instead, flexibility is predominantly framed as a cost-avoidance and investment-deferral mechanism, delivering economic value through avoided grid reinforcement, improved asset utilisation and reduced operational costs. This perspective is particularly relevant at distribution level, where the growing penetration of electric vehicles, heat pumps and distributed photovoltaic generation increasingly creates local congestion and operational constraints.

The EU DSO Entity Report on Distributed Flexibility Practices [26] confirms that DSOs are progressively expected to procure flexibility as an alternative or a complement to conventional grid reinforcement. This shift reflects both the rising costs and long lead times of network investments and the increasing availability of distributed flexible resources. Consequently, flexibility mechanisms addressing local grid needs are gaining strategic importance, making local flexibility markets and bilateral procurement arrangements more relevant for EV-based flexibility than traditional wholesale or balancing markets, which are primarily designed for system-level services.

The European flexibility market should be described as economically material but structurally emerging, with value realised primarily through avoided grid reinforcement and operational savings rather than through a mature, liquid market price [30]. This context provides a realistic and robust foundation for positioning EV-based flexibility solutions and supports phased, distribution-level deployment strategies such as those demonstrated in the Slovenian case.

Flexibility in Europe is not organised within a single, harmonised market structure. According to Eurelectric, DSOs currently access flexibility through a combination of rule-based approaches embedded in grid operation, network tariffs such as time-of-use schemes, flexible connection agreements and market-based procurement mechanisms. This diversity reflects differences in national regulatory frameworks, grid characteristics and levels of digital maturity. As a result, there is no one-size-fits-all market design for flexibility. Nevertheless, regulatory convergence is gradually increasing. The ongoing implementation of the Electricity Market Design reform and the introduction of ACER-mandated national flexibility needs assessments are driving partial harmonisation across Member States. These developments aim to align methodologies, clarify roles and create more consistent conditions for flexibility procurement, while still allowing adaptation to local contexts.

All major EU studies consistently conclude that distributed assets, including electric vehicles, become market-relevant only through aggregation. Individual EVs are typically too small and too uncertain in their availability to participate effectively in flexibility services on their own. However, when aggregated into portfolios, EVs can provide predictable and controllable flexibility that meets operational and market requirements. Aggregation reduces uncertainty, enables compliance with minimum bid sizes and allows flexibility to be allocated efficiently across different services. This finding directly supports the VPP based approach adopted in the Slovenian demonstrator, where EV flexibility is managed as part of an aggregated portfolio rather than as isolated assets.

Electric vehicles are consistently described in EU analyses as fast-responding, locally available and strongly aligned with decarbonisation objectives. These characteristics make EVs particularly suitable for addressing local grid constraints and short-term flexibility needs. At the same time, EV-based flexibility is not considered sufficient as a standalone solution. Its value is maximised when combined

with other flexibility resources such as battery energy storage systems, demand response from buildings and grid optimisation measures. Treating EV flexibility as a complementary resource rather than a single point of dependency improves system resilience and reduces operational risk. This perspective is fully aligned with the findings of the Slovenian demonstrator, where EVs are integrated alongside other assets within a broader flexibility framework.

Authoritative EU sources, including ACER [24], the Joint Research Centre [31] and the EU DSO Entity [16], consistently characterise the European flexibility market as being in a transition phase. The market is gradually evolving from pilot-based initiatives towards more structured and formalised procurement mechanisms, reflecting a shift from experimentation to early operational integration. At the same time, the traditionally high level of national diversity in flexibility arrangements is slowly giving way to partial harmonisation, driven by common regulatory frameworks, shared methodologies for flexibility needs assessment and increased coordination at EU level. This transition is further marked by a move away from ad-hoc and experimental solutions towards the definition of regulated flexibility products and clearer procurement processes, particularly at distribution level. Together, these developments indicate that flexibility is moving from a predominantly experimental concept towards a recognised and increasingly regulated component of electricity system operation, while still remaining in an intermediate stage of market maturity.

4.1.2 Market Drivers and Trends

The market potential for EV-based flexibility services is shaped by several reinforcing trends. Increasing EV penetration is driving higher and more concentrated charging demand, which in turn amplifies congestion risks in low- and medium-voltage networks. At the same time, policy frameworks at European and national level increasingly emphasise the role of flexibility and demand-side resources in enabling the energy transition. This is accompanied by ongoing digitalisation of distribution networks, which provides the technical foundation for monitoring, control and market integration of distributed flexibility.

The Slovenian demonstrator confirmed that these trends are not abstract future drivers but are already observable at local network level. As a result, EV-based flexibility services are becoming relevant even in advance of full regulatory maturity, particularly when deployed in controlled or localised market settings.

In addition, the increasing electrification of end-use sectors, most notably transport and heating, is significantly accelerating connection requests at the distribution level, placing further pressure on existing grid infrastructure. The Joint Research Centre [31] highlights that distribution system operators are already facing growing challenges related to grid capacity constraints and the integration of decentralised energy resources, reinforcing the need for flexibility solutions as a complement or alternative to traditional network expansion.

At the same time, flexibility markets across Europe remain structurally fragmented and are often implemented through pilot projects and local initiatives rather than fully standardised market mechanisms. This transitional state creates both uncertainty and opportunity: while revenue streams are still evolving, early deployments can capture value through congestion management, optimisation of network operation, and the deferral of grid reinforcement investments.

Finally, growing awareness of system-level costs is further strengthening the business case for flexibility. As grid investment needs increase across Europe, flexibility is increasingly recognised as a cost-efficient solution that enables better utilisation of existing infrastructure and reduces the need for capital-intensive upgrades. In this context, EV-based flexibility, particularly when aggregated and

digitally integrated, emerges as a scalable and strategically aligned solution that can support both market development and grid stability in parallel.

4.2 Value Proposition and Competitive Positioning

As electricity systems across Europe adapt to accelerating electrification and increasing decentralisation, the value proposition of EV-based flexibility services become increasingly multifaceted. DSOs, aggregators and end users are no longer evaluating solutions solely on the basis of technical performance, but rather on their ability to deliver system reliability, economic efficiency and long-term scalability within evolving regulatory and market frameworks. In this context, EV-based flexibility emerges as a strategically relevant option, offering distributed, fast-responding and locally available flexibility that directly addresses emerging grid challenges.

At European level, distribution grids are expected to integrate a rapidly growing number of electric vehicles in the coming decade, significantly increasing the need for flexibility-oriented solutions that can complement or defer traditional grid reinforcement investments. Against this background, the competitive positioning of EV-based services depends not only on their technical capabilities, but also on their ability to integrate seamlessly into existing operational processes, to coexist with alternative flexibility options, and to deliver clear and predictable value to different stakeholder groups.

The Slovenian demonstrator provides a concrete basis for assessing this value proposition under realistic conditions. By validating EV-based flexibility services in a real distribution network environment and in interaction with key market actors, the demonstrator enables a nuanced evaluation of where these services create the greatest added value, how they compare with competing solutions such as stationary storage or conventional demand response, and under which conditions they are most likely to be adopted. The following sections therefore examine the value proposition and competitive positioning of EV-based flexibility from the perspectives of DSOs, aggregators and EV users, taking into account both technical and market-oriented considerations.

4.2.1 Value Proposition for DSOs

For DSOs, the primary value proposition of the demonstrated services lies in their ability to deliver local flexibility on demand. By shifting, modulating or temporarily limiting EV charging, and in selected cases enabling bidirectional operation, DSOs can mitigate congestion, manage voltage deviations and improve overall network reliability. Importantly, these services allow DSOs to defer or avoid costly grid reinforcement investments, thereby optimising capital expenditure and improving the cost efficiency of network development over the long term.

Beyond immediate operational benefits, EV-based flexibility introduces a more dynamic and adaptive approach to network management. Instead of relying solely on static infrastructure upgrades, DSOs gain access to distributed, controllable resources that can respond to real-time grid conditions. This enhances the resilience of distribution networks, particularly in environments with increasing penetration of distributed energy resources and electrification-driven demand growth.

The Slovenian demonstration showed that such flexibility services can be effectively integrated into DSO operational workflows when supported by appropriate ICT platforms, standardised interfaces and clear coordination mechanisms with aggregators. This includes the definition of roles, responsibilities and control hierarchies, as well as transparent data exchange protocols that ensure reliable and secure communication between stakeholders.

The availability of forecasting and monitoring tools further enhances the reliability and predictability of service delivery, which is essential from an operational perspective. Improved load forecasting, state-of-charge visibility and real-time monitoring enable DSOs to better anticipate flexibility needs and activate resources in a timely and targeted manner. This reduces operational uncertainty and increases confidence in the use of EV-based flexibility as a complement to traditional grid management tools.

In addition, the demonstrator highlighted the importance of data quality, interoperability and latency in enabling effective control. High-frequency, accurate and standardised data flows between EVs, charging infrastructure and platform operators are critical for ensuring that flexibility services can be activated with sufficient precision and reliability. As services scale, these data-related aspects will become increasingly central to maintaining operational performance.

Finally, the transition towards large-scale adoption of such services will require continued alignment between technical capabilities and regulatory frameworks. DSOs will need clarity regarding procurement mechanisms, activation rights and remuneration structures for flexibility services. Establishing robust market and regulatory conditions will be essential to unlocking the full system value of EV-based flexibility and enabling its integration into standard DSO operations.

4.2.2 Value Proposition for Aggregators and VPP Operators

From the aggregator's perspective, EV-based flexibility enhances both portfolio diversity and responsiveness. EVs provide fast-acting, short-term flexibility that complements other distributed energy resources such as stationary storage or renewable generation. This combination allows aggregators to construct more resilient and adaptable flexibility portfolios, capable of responding to a wide range of grid and market signals.

Unlike more predictable assets, EVs introduce a highly dynamic and distributed flexibility potential, which, when effectively aggregated, can significantly increase the granularity and spatial relevance of services. This is particularly valuable in addressing local grid constraints, where geographically dispersed resources can be orchestrated to deliver targeted flexibility in specific network segments.

The Slovenian demonstrator confirmed that EV-based assets can be technically managed within existing VPP architectures, leveraging established aggregation, dispatch and monitoring functionalities. At the same time, it demonstrated the importance of further evolving these platforms to handle the increased variability and scale associated with EV fleets. This includes enhancements in real-time control capabilities, scalability of aggregation algorithms and more advanced optimisation strategies that account for competing constraints across multiple assets.

However, the demonstrator also highlighted that operational uncertainty, particularly related to EV availability, charging patterns and user behaviour, must be carefully addressed to ensure dependable service provision. Unlike stationary assets, EV participation is inherently linked to user needs and mobility patterns, which introduces variability in both availability and state of charge (SoC). Mitigating this uncertainty requires a combination of improved forecasting methods, probabilistic modelling and robust aggregation strategies that can compensate for individual asset variability at portfolio level.

Contractual arrangements and incentive mechanisms also play a key role in ensuring reliability. Aggregators must design user participation models that balance flexibility provision with user convenience, providing sufficient incentives while maintaining high levels of engagement and trust. This is closely linked to transparency in service participation, clear communication of benefits and limitations, and appropriate safeguarding of user preferences.

In addition, access to high-quality, real-time data is emerging as a critical enabler for effective aggregation. Direct or near real-time data streams from EVs and charging infrastructure allow aggregators to improve visibility of asset status, refine forecasts and optimise dispatch decisions. As such, strengthening data acquisition mechanisms, including closer integration with OEM systems and standardised communication interfaces, will be an important focus for future development.

Finally, as aggregators scale their operations, the ability to participate across multiple markets and revenue streams will become increasingly important. EV-based flexibility can potentially be stacked across services such as congestion management, balancing and ancillary services, provided that regulatory frameworks allow such multi-use of assets. Enabling this will require both technical capability and regulatory clarity, ensuring that aggregators can fully capture the value of EV flexibility while maintaining system reliability and transparency.

4.2.3 Value Proposition for EV Users

For EV users, participation in flexibility services offers both direct and indirect value, combining potential economic benefits with the opportunity to actively contribute to the energy transition. By allowing their vehicles to provide flexibility to the grid, through controlled charging or, in more advanced cases, bidirectional energy exchange, users can benefit from reduced energy costs, participation incentives, or additional revenues linked to energy services. At the same time, such participation supports broader system objectives, including improved grid stability, increased integration of renewable energy sources and the reduction of overall system costs.

However, the Slovenian demonstrator clearly showed that user acceptance is highly sensitive to how flexibility services are designed, implemented and communicated. While the technical concept of flexibility is generally well understood, willingness to participate depends strongly on the perceived impact on daily mobility and the level of complexity introduced for the user. Transparency, simplicity and the protection of core mobility needs emerged as decisive factors for adoption. In particular, users expect full clarity regarding when and how their vehicle is being used for flexibility purposes, as well as clear guarantees that their mobility requirements, such as required state of charge and vehicle availability, are always prioritised.

Services that operate largely in the background, require minimal user interaction and integrate seamlessly into existing charging behaviour demonstrate the highest acceptance potential. Automated or predefined charging strategies, where users can set simple preferences and retain control without the need for continuous engagement, were shown to significantly increase trust and usability. In contrast, solutions requiring active or frequent user decisions tend to face lower acceptance and are less scalable.

From a marketability perspective, these insights suggest that flexibility services must be designed as user-centric, opt-in solutions that prioritise convenience and predictability over technical optimisation. Participation should remain fully voluntary, with clear and stable incentives that are easy to understand and do not expose users to unnecessary risks or uncertainties. In addition, transparent communication of benefits, both financial and environmental, plays an important role in building user engagement and long-term trust.

Ultimately, achieving meaningful participation at scale will depend on aligning technical capabilities with user expectations. Flexibility services that combine economic value with high usability, low intrusiveness and strong guarantees on mobility performance are the most likely to succeed. This highlights the need for a design approach where user experience is treated as a central component of the value proposition, rather than a secondary consideration.

4.2.4 V2X Value Proposition for Charging Infrastructure Providers and EV Manufacturers

The value proposition of V2X for both charging infrastructure providers and electric vehicle manufacturers lies in the transformation of electric mobility into an integrated part of the energy system. For charging station operators, V2X enables the transition from a purely transactional charging business to a multi-functional energy service platform. Through bidirectional energy flows, charging infrastructure can generate additional value by participating in grid services such as demand response, congestion management, and energy arbitrage, while also improving asset utilisation and reducing operational costs. This shift allows charging providers to position themselves as active participants in local energy markets and flexibility ecosystems.

For automotive manufacturers, V2X enhances the overall value of electric vehicles by extending their functionality beyond mobility. Vehicles become flexible, distributed energy assets capable of providing services to the grid, buildings, and other users. This creates new opportunities for service-based business models, including revenue sharing from flexibility markets, energy service integration, and digital platform offerings. At the same time, V2X can contribute to lowering the total cost of ownership for end users by enabling the monetisation of battery capacity, thereby strengthening the attractiveness and competitiveness of electric vehicles.

From a system perspective, V2X creates shared value across the ecosystem by supporting grid stability, enabling higher penetration of renewable energy sources, and reducing the need for costly grid reinforcement. As such, it represents a key enabler of the convergence between the transportation and energy sectors, positioning both charging infrastructure providers and EV manufacturers as critical stakeholders in the emerging flexibility market.

4.3 Business Models and Revenue Mechanisms

The transition towards a more electrified and decentralised energy system is not only a technical challenge but also an economic and organisational one. As EV share increases across Europe, distribution grids carry the main burden of integrating new electric loads and distributed resources, making cost-efficient flexibility solutions a strategic priority for DSOs and aggregators alike. The viability of EV-based flexibility services depends strongly on the availability of appropriate business models (BMs) and sustainable revenue mechanisms. Unlike traditional grid investments, flexibility services are operational, rely on distributed assets owned by third parties, and require continuous coordination between multiple actors, shifting the economic focus from capital expenditure towards operational optimisation, contractual arrangements and performance-based remuneration. The Slovenian demonstrator provides valuable insight into how such business models can be structured in practice. By validating aggregator-centric service models and testing different interaction patterns between EV users, aggregators and DSOs, the demonstrator enables an assessment of how revenues can be generated, shared and stabilised under real market conditions. This section builds on the initial SI demo BMs developed in Deliverable D1.4 [10], where two BMs were defined for the Slovenian demonstrator (the Virtual Power Plant Business Model and the Flexibility Services operated by Distribution System Operators Business Model) using the Business Model Canvas (BMC) and Value Proposition Canvas (VPC) methodology. Following the completion of the demonstration and the KPI evaluation presented in Section 3.7, these initial BMs are updated and re-presented using the Service Business Model Canvas (SBMC) format, which captures the resources, activities, costs, value propositions, relationships and revenues of all involved stakeholders, customers, the service provider and key partners, within a single integrated canvas. The transition from BMC to SBMC is motivated by

the multi-stakeholder nature of V2X flexibility services, where value is co-created through the closely coordinated interaction of the Aggregator, DSO, CPO, V2X CS manufacturer and EV users [32].

The update of the BMs was informed by four main inputs: (i) the KPI interpretation results presented in Section 3.7; (ii) expert knowledge gathered during demonstration testing; (iii) lessons learned from the deployment process (Section 3); and (iv) the assessment of the current regulatory and market environment in Slovenia, where the local flexibility market is not yet established and V2X-compatible EVs are not yet widely available. Two updated SBMCs are presented in the following sections, the Virtual Power Plant Business Model (Section 4.3.1) and the Flexibility Services operated by Distribution System Operators Business Model (Section 4.3.2), followed by an analysis of revenue stability and risk factors (Section 4.3.3).

4.3.1 Virtual Power Plant Business Model and related SBMC

The VPP BM represents the service-oriented provision of V2X flexibility, in which the Aggregator (GEN-I in the Slovenian case) takes the role of service provider and is responsible for operating the VPP, while the DSO acts as the main customer procuring flexibility services for grid operation needs. The CPO and the V2X CS manufacturer are key partners, providing the V2X charging infrastructure and the enabling hardware and software, respectively. This allocation of roles is the key differentiating feature of the VPP BM with respect to the "Flexibility Services operated by DSOs" BM presented in Section 3.2, where the DSO assumes the role of service provider and the Aggregator becomes the customer.

Within the VPP model, the VPP aggregates distributed energy resources, in the Slovenian case specifically V2X-enabled EV batteries, into a coordinated flexibility portfolio. The Aggregator's core business logic is to optimise and dispatch the aggregated flexibility across different electricity markets, including balancing markets (mFRR, aFRR) and local flexibility services procured by the DSO (congestion management, voltage control). A key activity is to maximise the utilization rate of the portfolio across multiple markets simultaneously, which is enabled by the larger volumes obtained through V2X integration. Through digital platforms, real-time data exchange and contractual agreements with the DSO and CPOs, the Aggregator transforms EV batteries into commercially viable flexibility assets.

It should be noted that the local flexibility market in Slovenia is not yet established and EVs compatible with V2X technology are not yet widely market ready, both prerequisites for the full-scale deployment of the VPP BM. The SBMC presented in Table 3 therefore describes the BM configuration that becomes operationally applicable once the market, EV availability, regulation and technology reach the required maturity level. The cost structure, key resources, activities, value proposition, relationships, channels and revenue streams for the Aggregator (service provider), DSO (customer), CPO and V2X CS manufacturer (partners) are presented in Table 3.

We acknowledge that EV users are a fundamental element of the overall ecosystem, as they ultimately drive demand, influence utilization levels, and affect key parameters such as revenues, pricing structures, incentives, and demand-related risks.

However, within the scope of the analysed BMs, the primary focus is placed on the Aggregator and the DSO as the central actors. Consequently, EV users are not explicitly analysed as a standalone stakeholder. Instead, their impact is indirectly captured through the operational and market behaviours of the CPO and, where relevant, through assumptions embedded in the Aggregator and DSO perspectives.

While not explicitly represented, EV users remain a critical underlying driver of the business model. Their influence is implicitly reflected in cost structures, incentive mechanisms, utilisation rates, and

risk factors (e.g. variability in charging demand and participation in flexibility schemes). This ensures that their role is adequately considered without introducing unnecessary complexity at the stakeholder modelling level.

Table 3: SBMC for Virtual Power Plant Business Model

	Cost Structure	Key Resources	Key Activities	Value Proposition	Relationship	Channels	Revenue Stream
DSO	<ul style="list-style-type: none"> - Flexibility procurement payments - Digital platform for communication with aggregator 	<ul style="list-style-type: none"> - ADMS for grid management and data collection - Local market platform - Big data platform (Lambda) for problem detection and signal sending 	<ul style="list-style-type: none"> - Flexibility request and activation signal - Predicting needs for flexibility - Creation of contracts with Aggregators and data exchange with TSO 	<ul style="list-style-type: none"> - Maintaining grid stable (congestion management, voltage control) - Deferral of investments - Bridging current overloads on LV - Integration of users into the LFM, enabling them to become active consumers 	<ul style="list-style-type: none"> - Flexibility related contract with aggregator 	<ul style="list-style-type: none"> - ADMS interface and Local Market Platform - EVT 	<ul style="list-style-type: none"> - Avoided grid reinforcement costs - Reduction of operating costs - Reduction of technical losses
Aggregator	<ul style="list-style-type: none"> - Upgrade of VPP - V2X management platforms - Optimization and forecasting tools - Development of information exchange platform - Integration with EVT 	<ul style="list-style-type: none"> - VPP platform - V2X aggregation platforms - information exchange platforms 	<ul style="list-style-type: none"> - Optimal flexibility aggregation and provision of services - Participation in balancing and local markets - Lower cost of energy for customers - Management of V2X CSs based on activation signal - Monitoring of units and reporting to DSO 	<ul style="list-style-type: none"> - Increased flexibility in portfolio - Cooperation in the market - Provision of flexibility services - Optimal management of V2X flexibility - Contribute to the increase of the hosting capacity for the grid - Participation in multiple markets simultaneously due to larger volumes 	<ul style="list-style-type: none"> - Contracts with DSO, CPO - Exchange of data with DSO about flexibility - Informing CPO and consequently EV users about flexibility provision 	<ul style="list-style-type: none"> - Digital platforms for communication between markets, aggregators, DSOs and CPOs - Smart meters - DSO and CPO backends -Local Market Platform (FlexIS) 	<ul style="list-style-type: none"> - DSO contracts, related to local services - Balancing services revenues - CPO contracts

			- Help in development of LFM	- Lower cost of energy for customers			
CPO	<ul style="list-style-type: none"> - Investment into building of V2X CS network - Digital platform for communication with aggregator - Digital platform or APP for communication with EV users 	<ul style="list-style-type: none"> - Large network of CSs compatible with V2X - Active EV users as flexibility sources - Parking spots with CSs 	<ul style="list-style-type: none"> - Centralised control over CSs - Monitoring the operation of charging station - Maintenance of CSs - Communication with EV users (showing benefits, informing EV users about flexibility requests etc.) - Providing CS data to the Aggregator - Implementation of a user incentive system to encourage appropriate behaviour 	<ul style="list-style-type: none"> - Monetization of V2X capabilities - Opportunity to increase circle of EV users - End users actively participate at energy markets - Provision of charging services and parking spaces equipped with CSs - Offering charging services with added benefits when flexibility provision is enabled by EV users - Lower price of charging for end users 	<ul style="list-style-type: none"> - Integration of V2X CSs in VPP portfolio - Exchange of CSs and EV related data with aggregator - Contract with aggregator 	<ul style="list-style-type: none"> - Digital platform for communication with aggregator - CSs management and monitoring platform - Digital platform or APP for communication with EV users 	<ul style="list-style-type: none"> - Flexibility share revenues based on aggregator contract - Availability fees - Charging fees - Parking fees
V2X station manufacturer	<ul style="list-style-type: none"> - Development of V2X prototype CSs - R&D costs - Certification - Promotion and awareness-raising of new technologies 	<ul style="list-style-type: none"> - V2X prototype CSs - advanced user web interfaces 	<ul style="list-style-type: none"> - Hardware and software provision - Warranty and routine maintenance - Customer support - Quality assurance of CSs - Capture of measurements - Software development 	<ul style="list-style-type: none"> - Introduction of new technologies and products - V2X Market - Introduction of new approach: distributed charging system with a one high-power cabinet and multiple charging posts/dispensers 	<ul style="list-style-type: none"> - Supply of V2X CSs to the CPO - B2B contracts - Data provider with advanced user web interfaces 	<ul style="list-style-type: none"> - Proxy for data provision from CSs to CPO - Advanced user web interfaces 	<ul style="list-style-type: none"> - Hardware and software sales - SLA (service level agreement) - Data provision with advanced user web interfaces



			<ul style="list-style-type: none">- Development of new CSs- Participation in standardization activities and monitoring of the latest standards	<ul style="list-style-type: none">- Advanced user interface for data acquisition, monitoring and access			
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Main points from the SBMC for Virtual Power Plant Business model (Table 3):

- A key role of the Aggregator is to increase the flexibility potential of its portfolio through V2X integration, enabling larger offers, participation in multiple markets simultaneously, more efficient management of distributed flexibility assets and a measurable contribution to the increase of hosting capacity for the grid.
- The CPO provides and operates the V2X charging infrastructure (V2X compatible CSs and associated parking spaces) and plays an active operational role through centralised CS monitoring and control, data exchange with the Aggregator, communication with EV users, and implementation of incentive schemes encouraging appropriate user behaviour.
- The V2X CS manufacturer supplies the enabling hardware and software, including prototype V2X CSs, advanced user interfaces and support services, thereby contributing to the scalability and maturity of the V2X ecosystem.
- EV users, although not represented as a separate stakeholder layer in the SBMC, act as distributed flexibility providers through the CPO; in return, they could benefit from additional service-related incentives.
- Revenue is generated primarily by the Aggregator, through DSO contracts for local flexibility services, participation in balancing markets and contracts with CPOs. The DSO benefits indirectly through avoided grid reinforcement costs, reduced operating costs and lower technical losses.
- The cost structure spans investments in digital platforms and optimization tools, deployment and operation of V2X charging infrastructure, development and maintenance of V2X hardware and software, and payments for flexibility services.

4.3.2 Flexibility Services operated by Distribution System Operators Business Model and related SBMC

The "Flexibility Services operated by DSOs" BM represents the procurement-oriented provision of V2X flexibility, in which the DSO takes the role of service provider and is responsible for establishing, operating and further developing the local flexibility market. The Aggregator acts as the main customer, offering flexibility from its V2X-enabled VPP portfolio to the local flexibility market and responding to procurement signals issued by the DSO. The CPO and the V2X CS manufacturer are key partners, providing the V2X charging infrastructure and the enabling hardware and software, respectively. This allocation of roles, DSO as service provider and Aggregator as customer, is the mirror image of the VPP BM described in Section 4.3.1 and constitutes the key structural difference between the two BMs developed in the Slovenian demonstrator.

Within this model, the DSO identifies grid constraints such as congestion or voltage violations, predicts flexibility needs in terms of amount, time and location, and procures flexibility from aggregators through the local flexibility market platform. Aggregators provide aggregated flexibility from distributed resources, including V2X-enabled EVs, which can be activated upon request to support grid stability. The DSO coordinates the full procurement and activation process through a set of digital tools, the Advanced Distribution Management System (ADMS), the Local Market Platform (FlexIS) and the Big Data platform (Lambda), which together enable grid monitoring, problem detection, tender publication and activation signal dispatch. By integrating flexibility services into grid operation in this way, the DSO can manage local network constraints more efficiently, defer costly grid reinforcement investments and improve the hosting capacity of the distribution network.

The cost structure, key resources, activities, value proposition, relationships, channels and revenue streams for the DSO (service provider), Aggregator (customer), CPO and V2X CS manufacturer (partners) in the context of this BM are presented in Table 4.

Table 4: SBMC for Flexibility Services operated by Distribution System Operators Business Model

	Cost Structure	Key Resources	Key Activities	Value Proposition	Relationship	Channels	Revenue Stream
Aggregator	<ul style="list-style-type: none"> - Optimization and forecasting tools - Integration with EVT - V2X management platforms - Upgrade of VPP - Development of information exchange platform 	<ul style="list-style-type: none"> - VPP platform - Aggregator backend for preparation of bids - V2X aggregation platforms - Information exchange platforms 	<ul style="list-style-type: none"> - Flexibility potential assessment of V2X portfolio - Activation risk assessment - Creation of bids - Participation in LFM - Optimal offers to the energy market - Management of V2X CSs based on activation signal 	<ul style="list-style-type: none"> - Access to the LFM, increases revenue potential - Enhancing utilization of VPP portfolio - Active participation of end users on LFM - Enhancing flexibility product portfolio - Lower cost of energy for customers 	<ul style="list-style-type: none"> - Contract with DSO related to the provision and activation of requested flexibility services - Exchange of data with DSO about flexibility 	<ul style="list-style-type: none"> - Communication through Local Market platform FlexIS - Digital platforms for communication between markets, aggregators, DSOs and CPOs 	<ul style="list-style-type: none"> - Flexibility services activations payments (based on the contract with DSO) - Availability fees
DSO	<ul style="list-style-type: none"> - ADMS integration and upgrade - Development of Local Market Platform - Development of Big data platform (Lambda) - Forecasting tools - Integration with EVT - Flexibility procurement payments 	<ul style="list-style-type: none"> - Local Market platform - ADMS for grid management and data collection - Big data platform (Lambda) for problem detection and signal (procurement and activation) sending - Congestion and voltage problems forecast 	<ul style="list-style-type: none"> - Predicting flexibility needs (time, amount location) - Establish the LFM and the FlexIS environment, and further develop them in collaboration with other stakeholders - Procurement of flexibility via Local Market Platform - Publishment of tenders on platform, sending activation signals - Grid monitoring - Creation of contracts with Aggregators and data exchange with TSO 	<ul style="list-style-type: none"> - Development of the flexibility market - Maintaining grid stable (congestion management, voltage control) - Deferral of investments - Bridging current overloads on LV - Easier planning - Unification of the platform for different Agg., More Agg and more flexibility services - Decreasing GHG emissions 	<ul style="list-style-type: none"> - Contract with Aggregator for provision of flexibility service - Exchange of data with Aggregator about flexibility - Operator of LFM - Exchange of data with TSOs on the state of the network and the capacities of flexibility sources 	<ul style="list-style-type: none"> - Local Market Platform - EVT - Smart meters 	<ul style="list-style-type: none"> - Avoided grid reinforcement costs - Reduction of operating costs - Reduction of technical losses

		(flexibility prediction)		- Higher utilization of the distribution grid - Higher production from DER - Increase in hosting capacity - Active users			
CPO	<ul style="list-style-type: none"> - Investment into building of V2X CS network - Digital platform for communication with aggregator 	<ul style="list-style-type: none"> - Large network of CSs compatible with V2X - Active EV users as flexibility sources - Parking spots with CSs 	<ul style="list-style-type: none"> - Monitoring the operation of charging station - Management of V2X CSs based on aggregator signal - Providing CS data to the Aggregator - Implementation of a user incentive 	<ul style="list-style-type: none"> - Monetization of V2X capabilities - Opportunity to increase circle of EV users - Offering charging services with added benefits when flexibility provision is enabled by EV users 	<ul style="list-style-type: none"> - Exchange of CSs and EV related data with aggregator - Integration of V2X CSs in VPP portfolio - Contract with aggregator 	<ul style="list-style-type: none"> - CSs management and monitoring platform - Digital platform for communication with aggregator - Digital platform or APP for communication with EV users 	<ul style="list-style-type: none"> - Flexibility share revenues based on aggregator contract - Availability fees - Charging fees - Parking fees
V2X station manufacturer	<ul style="list-style-type: none"> - Development of V2X prototype CSs - R&D costs - Certification - Promotion and awareness-raising of new technologies 	<ul style="list-style-type: none"> - V2X prototype CSs - Advanced user web interfaces 	<ul style="list-style-type: none"> - Hardware and software provision - Warranty and routine maintenance - Customer support - Quality assurance of CSs - Capture of measurements - Software development - Development of new CSs - Participation in standardization activities and monitoring of the latest standards 	<ul style="list-style-type: none"> - Introduction of new technologies and products - V2X Market - Introduction of new approach: distributed charging system with a one high-power cabinet and multiple charging posts/dispensers - Advanced user interface for data acquisition, monitoring and access 	<ul style="list-style-type: none"> - Supply of V2X CSs to the CPO - B2B contracts - Data provider with advanced user web interfaces 	<ul style="list-style-type: none"> - Proxy for data provision from CSs to CPO - Advanced user web interfaces 	<ul style="list-style-type: none"> - Hardware and software sales - SLA (service level agreement) - Data provision with advanced user web interfaces

Main points from the SBMC for Flexibility Services operated by Distribution System Operators Business Model (Table 4):

- The DSO acts as both service provider and market operator: in addition to procuring and activating flexibility, the DSO establishes and further develops the local flexibility market.
- DSO's value proposition combines grid stability (congestion management, voltage control), deferred reinforcements and higher hosting capacity with, distinctively, the development of the flexibility market itself, including the unification of the platform for different aggregators and more active end-user participation. For the Aggregator, the value proposition is access to the local flexibility market as an additional revenue channel, enhanced VPP utilization and a broader flexibility product portfolio.
- The CPO operates the V2X charging infrastructure and manages the CSs based on the Aggregator's activation signal, originating from the DSO via the Local Market Platform, while exchanging CS and EV data with the Aggregator and implementing user incentive schemes.
- The V2X CS manufacturer supplies the enabling hardware and software (prototype V2X CSs and advanced user interfaces); its role is essentially equivalent to that in the VPP BM, since the technology layer remains the same regardless of which actor procures the flexibility.
- The revenue structure is the following: direct revenues flow to the Aggregator (activation payments, availability fees), while the DSO captures value indirectly through avoided reinforcements, reduced operating costs and lower technical losses. Selected costs are correspondingly split between the DSO (ADMS upgrades, Local Market Platform and Lambda development, forecasting tools, procurement payments) and the Aggregator (VPP upgrade, V2X management and information exchange platforms).

4.3.3 Revenue Stability and Risk Factors

A central finding of the Slovenian demo is that revenue stability remains one of the main challenges for market deployment. Current regulatory and market frameworks do not yet provide long-term visibility or predictable income streams for flexibility services at distribution level. This uncertainty is particularly pronounced for advanced services involving bidirectional charging.

Additional risk factors include potential regulatory changes, varying levels of technology maturity, and fluctuations in EV availability. Effective risk management therefore requires diversified service offerings, robust contractual frameworks and close, continuous coordination between aggregators and DSOs.

In addition to the revenue and risk considerations outlined above, the demonstration process revealed a set of concrete stakeholder pains and corresponding pain relievers that directly affect the viability of both business models. While the SBMCs describe how value is created and captured, the analysis of pains and pain relievers provides a more practice-oriented view of the main barriers, concerns and enabling measures affecting the implementation of V2X flexibility services. Therefore, the identified pains and pain relievers presented in Table 5, provide an important complementary perspective for understanding the practical conditions for the successful uptake and scaling of both the VPP BM and the Flexibility Services operated by Distribution System Operators BM.

Table 5: Current main stakeholders related pains and corresponding pain relievers related to the VPP BM and the Flexibility Services operated by DSO BM

Actors	Current pains	Pain relievers
DSO	<ul style="list-style-type: none"> - Excessive peak load, - Main's voltage is too high or too low, - Insufficient capacity to connect new sources of electricity or new loads. 	<ul style="list-style-type: none"> - Using flexibility, - Connection of V2X CSs.
Aggregator	<ul style="list-style-type: none"> - Disunity of processes, - Incompatibility, - EVs are not a stable source of flexibility, unpredictable behaviour, incentives needed, - Planning of flexibility capacities in correlation with UCs and services, - Challenges related to EV and CS compatibility, not all EVs are capable of V2X technology (currently EV data not available due to interoperability issues), - Range anxiety and battery degradation fear, - Trust in technology, - Slower rise of EV share than expected, - Reliable communication between markets, aggregator and DSO etc. 	<ul style="list-style-type: none"> - Unit control, - Reliable execution and flexibility management, - Scaling, - Contract with CPO.
CPO	<ul style="list-style-type: none"> - N x X vs 1 x X (where and how many), - Time and location are unpredictable, - Different SoC than expected, - Number of EVs is too small to determine pattern, - Customer acquisition, - Adequacy of customer environment, - Customer willingness to cooperate, - EV user, who does not comply with the agreed behaviour, - Enhancing the system to reward compliant users and penalise those, who do not adhere to expected behaviour, - Seasonal behaviour of EV users, due to different habits and grid tariffs, - EV user payments, - EV user cannot participate successfully because there is no regulation to support it, 	<ul style="list-style-type: none"> - Maintenance and monitoring of CSs, - Implementation of a user incentive system to encourage appropriate behaviour, - Communication with EV users, - Compensation for users to release pain points (e.g., free charging).
CS manufacturer	<ul style="list-style-type: none"> - Errors at CSs, - EV-charger compatibility with car OEMs (V2G functionality), - Lack of opportunities for two-way CSs, - Limited number of EVs with two-way charging, - Standardization not yet developed, - ISO15118-20 (more different versions of standard). 	<ul style="list-style-type: none"> - Participation in interoperability testing with EV OEMs, - Development of robust CS and control algorithms, - Continuous development of the CSs, - Participation in standardization activities and monitoring of the latest standards, - Development of universal solutions capable of supporting multiple standards, - Promotion and awareness-raising of new technologies, - Participation in research and development projects.

The pains reported across the four stakeholder groups cluster into four recurring themes:

- Grid-level pains of the DSO (excessive peak load, voltage deviations, insufficient capacity to connect new sources or loads) are directly addressed by both BMs.
- Technology and interoperability pains → EV/charger compatibility, limited availability of V2G-capable EVs, missing EV data, and unification of the ISO 15118-20 standard. Corresponding pain relievers rely on interoperability testing with EV OEMs, universal solutions supporting multiple standard variants, and active participation in standardization and R&D activities.
- User behaviour and incentive pains → unpredictable arrival times and SoC, seasonal effects, range anxiety, battery degradation fears, and non-compliance with agreed behaviour. Pain relievers centre on user incentive schemes, clear communication with EV users, compensation mechanisms and tariff designs that reward desirable behaviour.
- Market and regulatory readiness pains → slower than expected EV uptake, the absence of an established local flexibility market, and the lack of regulation enabling end-user participation.

4.4 Market Barriers, Enablers and Readiness Assessment

The deployment of EV-based flexibility services take place within a complex market environment shaped by regulatory frameworks, technological maturity and the readiness of system actors to adopt new operational models. While the rapid growth of electric mobility creates a clear need for flexibility solutions, their large-scale market uptake is neither automatic nor uniform across regions. DSOs, who manage almost the entire low- and medium-voltage network in Europe, are at the centre of this transition, as distribution grids are expected to integrate the majority of new electric vehicles and other distributed energy resources in the coming decade.

Against this background, the successful deployment of EV-based flexibility depends on a balance between market barriers and enabling factors. Regulatory uncertainty, limited standardisation maturity and fragmented stakeholder responsibilities can significantly slow down adoption, even where technical solutions are already available. At the same time, increasing EV penetration, digitalisation of grid operation and the emergence of flexibility-oriented regulatory instruments create favourable conditions for market development.

The Slovenian demonstrator provides a realistic basis for assessing this balance under practical conditions. By operating EV-based flexibility services in a real distribution network and within existing regulatory constraints, the demonstrator makes it possible to distinguish between barriers that are structural and require policy-level intervention, and those that can be addressed through improved system design, coordination mechanisms or market arrangements. The following sections therefore assess market barriers, enablers and overall readiness for EV-based flexibility deployment, drawing on concrete lessons learned from the Slovenian context while maintaining relevance for broader European application.

4.4.1 Market Barriers

The Slovenian demonstrator identified several structural barriers that currently limit the market uptake of EV-based flexibility services. These barriers are not uniform in nature: some are transitional and will resolve as electric mobility matures, while others are structural and require deliberate intervention at policy, market design or industry coordination level. Distinguishing between the two is essential for shaping realistic exploitation strategies. Limited availability of V2X-capable vehicles and bidirectional charging stations falls into the transitional category and is expected to ease progressively as OEM portfolios expand and standardised hardware reaches volume production. In contrast,

regulatory uncertainty regarding aggregation, V2X service participation and remuneration mechanisms, the absence of standardised flexibility products at distribution level, and the inherent complexity of multi-stakeholder coordination represent structural barriers that will not be resolved by technological progress alone.

A second category of barriers emerges from the gap between the formal existence of communication and charging standards and the maturity of their practical implementation. Although ISO 15118-20 and OCPP provide the conceptual foundation for V2X interoperability, their support across electric vehicles, charging stations and Charging Station Management Systems remains uneven. Differences in vendor interpretation, partial feature coverage and parallel coexistence of OCPP 1.6 with vendor-specific smart charging extensions and the more recent OCPP 2.1 mean that aggregators scaling from a single CPO to a broader portfolio face a multiplicity of integration dialects rather than a single standardised interface. Certificate trust infrastructure required for secure bidirectional operation, including the V2G Root Certificate Authority and contract certificate management, is also not yet operational at scale across EU. These factors do not prevent V2X deployment, but they materially extend onboarding timelines and increase per-site integration cost, which directly affects the economic case for commercial scaling.

A third category of barriers relates to measurement, settlement and liability. The settlement of flexibility activations requires time-aligned, calibrated energy data with a clearly designated meter of record, yet there is currently no harmonised expectation across DSOs, CPOs and aggregators regarding which measurement point should settle a given activation, what accuracy class is contractually required, or how systematic offsets between requested and delivered power are to be allocated between parties. In parallel, the aggregator typically carries operational liability for non-delivery toward the DSO while remaining dependent on a chain of components owned by other actors, including the electric vehicle, the charging station, the CSMS and the underlying communication infrastructure. In the absence of mature contractual frameworks for cascading this risk across the value chain, aggregators tend to price residual uncertainty conservatively into their bids, which dampens market signals and slows the transition from demonstration to commercial deployment. Taken together, these barriers position EV-based flexibility services for continued progress within pilot projects and structured early market applications, while underlining the conditions that must be addressed for full commercial roll-out.

4.4.2 Market Enablers

At the same time, the Slovenian demo identified several strong enablers for future deployment. Increasing EV penetration will naturally expand the available flexibility pool, while ongoing regulatory development is expected to gradually clarify the role of flexibility markets at distribution level. Digitalisation of DSO operations and standardisation of communication and data exchange further reduce technical and organisational barriers.

The demonstrator clearly showed that early and structured engagement between DSOs, aggregators and regulators significantly improves deployment conditions and accelerates learning.

4.4.3 Market Readiness and Path to Commercialisation

Overall, the services demonstrated in Slovenia can be considered to have reached an advanced pilot stage. While many technical components achieved TRL levels of 8 to 9, full commercial deployment requires further regulatory clarification, wider availability of V2X-capable assets and the establishment of stable market mechanisms.

A phased commercialisation strategy is therefore recommended. Initial deployment should focus on controlled environments such as fleets, workplaces and residential communities, where operational conditions are more predictable. In this context, unidirectional smart charging services show high short-term marketability, while bidirectional V2X services represent a medium- to long-term opportunity.

4.5 Strategic Market Recommendations

Based on the findings and operational experience of the Slovenian demonstrator within the EV4EU project, several strategic priorities emerge that are critical for enabling the transition from pilot initiatives to scalable, market-based deployment of EV-based flexibility services.

A key recommendation is to prioritise the structured development of local flexibility markets, which represent the most practical and near-term entry point for EV-based services. These markets allow DSOs to procure flexibility services at the distribution level, where constraints are most acute and where EV charging load is increasingly concentrated. By enabling localised procurement, system operators can more efficiently manage congestion, defer grid reinforcement investments, and improve overall asset utilization. Importantly, local flexibility markets also provide a clear and accessible participation pathway for aggregators and EV users, facilitating early monetization opportunities and gradual market maturation.

To support this development, the continued implementation of regulatory sandboxes and pilot frameworks is essential. These mechanisms enable controlled experimentation with new market designs, tariff structures, and business models, while reducing regulatory risk for market participants. The Slovenian demonstrator has shown that such environments are instrumental in identifying practical barriers, ranging from data access and interoperability issues to contractual and verification challenges, and in testing solutions under real-world conditions. Regulatory authorities should therefore actively support and institutionalise sandbox approaches, ensuring that learnings are systematically translated into formal regulatory frameworks.

Another critical priority is the strengthening of cooperation models between aggregators and DSOs. Effective integration of EV-based flexibility depends on clear roles, standardised communication protocols, and aligned incentives between these actors. The demonstrator highlights the importance of transparent data exchange, reliable forecasting, and coordinated activation processes to ensure that flexibility services can be delivered in a predictable and system-relevant manner. Moving forward, the development of standardised interfaces and operational procedures will be key to reducing transaction costs and enabling scalability across different network areas and markets.

The introduction of V2X services should follow a phased and pragmatic approach, aligned with both technological advancements and regulatory readiness. While the technical feasibility of bidirectional charging has been successfully demonstrated, widespread deployment still requires further progress in vehicle compatibility, charging infrastructure, grid codes, and market rules. In the near term, focus should remain on unidirectional smart charging (V1G) solutions, which already provide substantial flexibility value. As standards mature and cost barriers decrease, V2X services can be progressively integrated, unlocking additional value streams such as energy arbitrage, ancillary services, and backup power applications.

The Slovenian demonstrator has clearly confirmed the technical feasibility, system relevance, and growing market potential of EV-based flexibility services. Demonstrated capabilities include reliable aggregation of EV load, response to grid signals, and integration into DSO operational processes. At the same time, the project has provided valuable insights into user behaviour and acceptance,

indicating that while there is general openness to participation, clear value propositions, minimal user intervention, and trust in service providers are essential for sustained engagement.

Nevertheless, several challenges remain that must be addressed to enable full commercial deployment. In particular, regulatory design and revenue stability continue to represent key uncertainties. The absence of standardised market mechanisms and long-term price signals limits investment confidence for aggregators and infrastructure providers. Addressing these issues will require coordinated action at both national and European levels, including the harmonization of flexibility market rules, clarification of roles and responsibilities, and the introduction of stable remuneration schemes.

Despite these challenges, the Slovenian demonstrator has achieved a high level of technical readiness and innovation maturity, providing a robust foundation for scaling EV-based flexibility services beyond pilot environments. The combination of validated technology, operational experience, and user insights positions the EV4EU project as a strong reference case for future deployments. With the right regulatory support, market design, and stakeholder coordination, EV-based flexibility can evolve from a promising concept into a mainstream component of the energy system, contributing to grid stability, cost efficiency, and the broader energy transition.

4.6 Future Plans for Innovation Development, KER Exploitation and Collaboration

The future deployment of EV-based flexibility services depend not only on the technical success of pilot demonstrations, but also on the ability to translate validated innovations into sustainable solutions that can be scaled, replicated and integrated into evolving energy system architectures. Across Europe, DSOs are increasingly recognised as key enablers of the energy transition, responsible for integrating electric mobility, renewable generation and flexible demand while maintaining system reliability and cost efficiency. In this context, continued innovation, structured exploitation of KERs and sustained collaboration among stakeholders are essential elements of long-term impact [16].

European experience from flexibility-focused research and innovation projects shows that successful scaling requires a clear post-project strategy that combines technical refinement, market alignment and regulatory engagement. Initiatives supported by the EU increasingly emphasise interoperability, digitalisation and coordinated action between DSOs, aggregators, technology providers and market platforms as prerequisites for effective deployment of EV-based flexibility at scale. Without such coordination, promising innovations risk remaining confined to isolated pilots [27].

Within this framework, the Slovenian demonstrator provides a strong basis for defining future plans. The validated innovations and KERs represent a portfolio that can evolve along differentiated pathways depending on maturity and market readiness, while the established collaboration structures offer a foundation for follow-up activities, joint exploitation and engagement with regulators. The following sections therefore outline future plans for innovation development, KER exploitation and collaboration, focusing on how the project results can be consolidated and expanded to support the broader roll-out of EV-based flexibility services in Slovenia and across Europe.

4.6.1 Strategic Outlook and Innovation Development

The outcomes of the Slovenian demonstrator establish a strong and credible basis for the continued development of the innovations and KERs generated within the project. Having successfully

demonstrated technical feasibility and operational relevance in real network conditions, future activities will increasingly focus on transitioning from pilot level validation towards consolidation, scaling and selective commercial deployment. This transition will not be driven by individual technologies alone, but by the coordinated evolution of technical solutions, service concepts and operational frameworks.

A central strategic objective for post project development is to maintain the integrated and system-oriented nature of the solutions. The Slovenian demonstrator confirmed that the value of EV based flexibility emerges most clearly when technical components, digital platforms and market mechanisms are developed in parallel and deployed as a coherent service offering. Future innovation activities will therefore prioritise alignment across these dimensions, ensuring that further technical improvements remain closely linked to real operational needs and market conditions.

At the same time, a key priority will be to ensure long-term user engagement. The sustainability and scalability of EV-based flexibility services depend on the ability to actively involve EV users over extended periods, building trust and delivering clear value propositions. To support this, future efforts will increasingly focus on establishing direct communication channels with electric vehicles, enabling more reliable and granular data acquisition directly from EVs. This will not only improve the quality and timeliness of operational data but also allow for more dynamic and user-centric service design, ultimately strengthening participation and retention.

From a technical perspective, future development will concentrate on improving robustness, scalability and interoperability of the validated solutions. Core components such as VPP platforms, EV aggregation models, forecasting tools and decision support systems have reached high levels of maturity and are suitable for deployment in broader operational contexts. Further work will focus on enhancing system performance under larger portfolios, increasing automation of operational processes and improving interoperability with external systems operated by DSOs, TSOs, CPOs and market platforms. Particular attention will be given to data quality, latency and cybersecurity, as these aspects become increasingly critical when moving from controlled pilot environments to commercial operation.

Advanced V2X functionalities will continue to be developed in an incremental and risk aware manner. While the Slovenian demonstrator confirmed their technical feasibility and potential system value, future work will focus on increasing reliability, reducing system complexity and addressing open questions related to battery degradation, asset lifetime and operational risk. This gradual approach allows innovation to continue without compromising user trust or system stability.

4.6.2 KER Exploitation and Business Evolution

The future exploitation of KERs will follow differentiated pathways that reflect their respective levels of maturity, market readiness and strategic relevance. KERs related to unidirectional smart charging, local flexibility aggregation and operational decision-support for DSOs and aggregators are expected to progress towards early commercial or pre-commercial deployment. These results already demonstrate a clear value proposition, relatively low dependency on unresolved regulatory issues and strong alignment with current market needs.

In contrast, more advanced KERs associated with bidirectional charging, flexible capacity contracts and sophisticated local flexibility markets will continue to be exploited through extended pilot activities, regulatory sandboxes and targeted demonstration projects. This approach allows further learning under real-world conditions while managing technical, regulatory and economic risks. At the same

time, it preserves a clear long-term pathway towards full market integration as enabling conditions mature.

Future exploitation activities will also focus on strengthening the business foundations of the developed KERs. This includes further clarification of intellectual property arrangements, definition of licensing and cooperation models, and, where appropriate, the establishment of joint exploitation strategies among partners. Such arrangements are particularly relevant for integrated solutions that span multiple organisational domains and require close cooperation between technology providers, aggregators and system operators.

Business model development will remain centred around an aggregator-led approach, with aggregators acting as the primary interface between EV users and system operators. Future service deployment is expected to initially focus on controlled environments such as fleets, workplaces, residential communities and municipal infrastructure, where operational conditions are more predictable and scaling risks can be managed more effectively. These early deployment contexts provide an important stepping stone towards broader market roll-out.

4.6.3 Collaboration, Scaling and Long-Term Vision

Sustained collaboration among project partners represents a cornerstone of future plans. The Slovenian demonstrator clearly showed that close cooperation between DSOs, aggregators, technology providers and research organisations significantly enhance both technical outcomes and market relevance. Future collaboration will therefore continue through follow-up projects, bilateral agreements, participation in Horizon Europe projects and joint market initiatives aimed at refining and scaling the developed solutions.

Engagement with regulators and policy makers will remain an integral part of post-project activities. Active participation in consultations, working groups and regulatory sandbox initiatives will support alignment with evolving regulatory frameworks and contribute to shaping future market design for flexibility services. Such engagement is particularly important for advanced services involving V2X, where regulatory clarity is a key prerequisite for wider deployment.

In parallel, the collaboration ecosystem will be gradually expanded to include additional stakeholders such as municipalities, fleet operators, CPOs and energy communities. Broadening the ecosystem supports replication of the developed solutions across different contexts, accelerates learning and increases overall impact. This inclusive approach also helps ensure that future developments remain responsive to a wide range of stakeholder needs.

In the long term, the vision emerging from the Slovenian demonstrator is a gradual transition from pilot-based implementation towards large-scale integration of EV-based flexibility into distribution system operation and, eventually, into coordinated DSO–TSO processes. This transition will be guided by incremental scaling, continuous learning and strong stakeholder coordination. Rather than pursuing rapid and potentially risky market entry, future plans emphasise a pragmatic and adaptive pathway that balances innovation with reliability, user acceptance and system stability.

4.6.4 Economic Perspective and Long-Term Development

The innovations and services demonstrated within the Slovenian pilot create a strong foundation for long-term economic development in the field of EV-based flexibility. As these solutions transition from pilot-level validation towards broader deployment, their economic relevance is expected to increase steadily. Rather than representing isolated technological advances, the developed innovations form

part of a broader transformation of the electricity system towards higher efficiency, flexibility and cost-effectiveness.

In economic terms, EV-based flexibility contributes to a more efficient utilisation of existing grid infrastructure. By actively managing charging demand and, in later stages, enabling bidirectional interaction, system operators can reduce peak loads, mitigate congestion and optimise network operation. This, in turn, reduces the need for costly grid reinforcements and defers capital-intensive investments. Over time, these avoided or postponed investments translate into lower system costs, which form a critical component of the overall cost of electricity supply.

The Slovenian demonstrator confirms that such efficiency gains are not purely theoretical but can be achieved through coordinated technical and market solutions. As flexibility services mature and scale, they are expected to become an integral part of the economic logic of distribution network operation.

4.6.5 Development of New Services and Market Offerings

Building on the validated solutions, future development will enable the emergence of new services that extend beyond the initial scope of the demonstrator. In the short to medium term, service evolution will focus on refined unidirectional charging solutions, local flexibility products and enhanced decision-support services for DSOs and aggregators. These services are well aligned with current regulatory frameworks and can be deployed with relatively low risk.

In the medium to long term, more advanced services are expected to emerge, including bidirectional flexibility products, flexible capacity contracts and integrated mobility-energy offerings. As regulatory frameworks evolve and V2X-capable assets become more widespread, these services will allow EVs to actively contribute to system balancing and local congestion management. The gradual introduction of such services will expand the range of value streams available to market actors, strengthening the overall economic viability of EV-based flexibility.

Importantly, the development of new services also creates opportunities for new business roles and cooperation models. Aggregators, technology providers, DSOs and service companies will increasingly operate within a shared flexibility ecosystem, supporting innovation, competition and service differentiation.

4.6.6 Impact on Electricity Prices and Charging Costs

One of the most significant long-term impacts of EV-based flexibility lies in its potential influence on electricity prices and charging costs. By reducing peak demand and improving load distribution, flexibility services help lower system operating costs and reduce exposure to extreme price events. Over time, this contributes to more stable wholesale electricity prices and lower balancing and congestion management costs.

At the end-user level, smarter charging and flexibility-based services enable EV users to access more favourable charging conditions. Charging can be shifted to periods with lower system costs or higher renewable generation, resulting in lower average charging prices. As these mechanisms become more widespread and automated, they reduce the cost of EV ownership and operation, making electric mobility more economically attractive to a broader range of users.

Although price impacts depend on regulatory design and market implementation, the Slovenian demonstrator confirms that flexibility-enabled charging creates the structural conditions necessary for cost reductions at both system and user level.

4.6.7 Acceleration of EV Adoption and Environmental Benefits

Lower and more predictable charging costs, combined with improved system integration, are expected to support increased adoption of electric vehicles. As economic barriers to EV ownership decrease, adoption is likely to extend beyond early adopters to mainstream users, including private households, fleets and commercial operators.

Increased EV uptake has direct environmental benefits through the reduction of local emissions and greenhouse gases from transport. When combined with flexibility-based charging strategies, these benefits are further amplified by higher utilisation of renewable energy sources. By aligning EV charging with periods of high renewable generation, the overall carbon intensity of electricity consumption for transport can be significantly reduced.

The Slovenian demonstrator highlights that EV-based flexibility is therefore not only a technical or economic innovation, but also a key enabler of broader sustainability objectives. The combined effect of system efficiency, lower costs, increased EV adoption and reduced emissions contributes to a more resilient, affordable and environmentally sustainable energy system.

In the long term, the innovations and services developed within the project are expected to contribute to a virtuous cycle. Improved flexibility reduces system costs, which supports lower electricity and charging prices. Lower costs encourage higher EV adoption, which in turn increases the available flexibility pool and strengthens the business case for further innovation. This cycle reinforces both economic efficiency and environmental performance, positioning EV-based flexibility as a cornerstone of the future electricity and mobility system.

5 Conclusions

Deliverable D7.4 – Lessons learned in Slovenian Demonstrator and Services Marketability report consolidates the outcomes of the Slovenian demonstrator implemented within the EV4EU project and translates operational experience into structured lessons learned and market-oriented insights. By combining qualitative analysis with quantitative results reported in previous deliverables D7.1 [1], D7.2 [3] and D7.3 [2] this report provides a comprehensive assessment of the technical, operational, regulatory and market dimensions of EV-based flexibility services.

The analysis confirms that EV-based flexibility has progressed from a conceptual innovation towards a technically viable and system-relevant solution, particularly at the distribution level. The Slovenian demonstrator successfully validated the integration of electric vehicles, smart charging (V1G) and bidirectional charging (V2X) into a VPP environment and demonstrated their interaction with DSOs and market mechanisms under realistic operating conditions. These results provide strong evidence that EV-based flexibility can support local grid operation and contribute to more efficient use of existing network infrastructure.

At the same time, the lessons learned clearly show that large-scale deployment is constrained not by a single factor, but by the combined maturity of technology, regulation, market design and stakeholder readiness. Technical challenges related to interoperability, system integration and reliability remain relevant, particularly for advanced V2X services. Operational experience highlights the importance of aggregation, automation and well-defined coordination mechanisms between aggregators, DSOs and other actors. Regulatory uncertainty and fragmented market frameworks continue to limit predictable revenue streams, reinforcing the need for phased deployment and continued regulatory evolution.

The marketability assessment confirms that the European flexibility market is economically material but structurally emerging. Flexibility is currently realised primarily through local and distribution-level mechanisms rather than through a single unified market. In this context, EV-based flexibility is most effectively positioned as a complementary resource, delivered through aggregation and targeted local services, and combined with other flexibility assets such as battery energy storage and demand response programmes. The demonstrator results support an exploitation pathway starting with mature V1G solutions and gradually introducing targeted V2X use cases as enabling conditions improve.

From an exploitation perspective, the Slovenian demonstrator provides a realistic and replicable reference case for future EV4EU activities and broader European deployment. The validated innovations and KERs demonstrate clear potential for scaling, particularly in controlled environments such as fleets, workplaces and residential communities. The findings underline the importance of early stakeholder engagement, close cooperation with DSOs and regulators, and alignment with evolving flexibility frameworks at both EU and national levels.

Overall, Deliverable D7.4 concludes that EV-based flexibility represents not only a credible but an increasingly essential component of future electricity systems, supporting electrification, renewable integration and the transition towards more resilient and efficient grids. Its successful transition from pilot projects to commercial deployment will require an incremental, coordinated and evidence-based pathway, combining technological maturation, market development and regulatory alignment. By capturing both achievements and remaining challenges, this deliverable provides a robust and actionable foundation for future exploitation within EV4EU and offers valuable guidance for the scalable deployment of EV-based flexibility solutions across Europe.

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