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Electric Vehicles Management for carbon neutrality in Europe

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Innovation Strategy: Update

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Disclaimer

This document has been produced in the context of the EV4EU[1] project. Views and opinions expressed in this document are however those of the authors only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

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[1] https://ev4eu.eu/

Executive Summary

The Innovation Strategy of the EV4EU project, originally defined in Deliverable D10.3 – Innovation Strategy [1], established a comprehensive framework for innovation management at consortium level. It described the strategic vision, governance structure, and methodological approach guiding the identification, assessment, development, and integration of innovative solutions throughout the project lifecycle. Prepared by GEN-I, the partner responsible for Innovation Management, D10.3 provided a shared reference point for all consortium members and ensured a coordinated approach to generating impactful, scalable, and market-oriented innovations.

At the end of the EV4EU project, this document represents both an evolution and a consolidation of the initial innovation strategy and a final report on the innovations actually developed, validated, and demonstrated within the project. While D10.3 [1] focused on defining processes and strategic principles, this final update reflects the practical outcomes of those principles as implemented across work packages, demonstrators, and partner activities.

Throughout the project duration, the innovation strategy proved to be a dynamic and effective instrument rather than a static plan. Under Task T10.2 – Innovation Strategy, implemented within WP10 - Knowledge transfer and Dissemination, the consortium continuously monitored innovation progress and, where necessary, adapted activities to reflect technological progress, market dynamics, regulatory developments, and feedback from real-world demonstrations. This adaptive approach ensured that EV4EU innovations remained aligned with stakeholder needs and that project results were developed in a way that maximized their relevance, usability, and exploitation potential.

As a result, EV4EU successfully delivered a broad portfolio of innovations covering technologies, digital tools, business models, and services related to electric mobility, V2X integration, flexibility markets, and grid operation. These innovations have reached varying levels of technological and innovation readiness and have been validated in multiple demonstration environments. The innovation portfolio reflects both incremental and breakthrough developments, addressing challenges such as smart and bidirectional charging, system interoperability, flexibility provisioning, user engagement, and sustainable grid integration of electric vehicles.

This final innovation report therefore goes beyond a procedural description of innovation management. It provides a consolidated overview of the concrete innovations generated by the EV4EU project, their scope, maturity, and demonstrated value, as well as their potential pathways for further development, deployment, and exploitation beyond the project lifetime. It confirms that the innovation strategy defined in D10.3 [1] successfully supported the transition from strategic planning to tangible, validated results.

The role of GEN-I, as Innovation Management Lead, was central to this process. GEN-I ensured alignment across the consortium, bridged technical and business perspectives, and supported partners in framing their results within a coherent innovation portfolio. The final set of innovations presented in this document demonstrates that the EV4EU innovation strategy effectively enabled the generation of robust, market-relevant outcomes and laid a solid foundation for future uptake, scaling, and commercialization of project results.

In conclusion, the completion of the EV4EU project confirms that Innovation Strategy D10.3 [1] was not only successfully implemented but also meaningfully extended through practice. The project leaves behind a validated set of innovations and a proven innovation management approach that can serve as a reference for future collaborative projects in the fields of electric mobility, energy systems, and V2X technologies.

A total of 113 innovations were developed within the EV4EU project, reflecting an outstanding level of excellence, scale, and maturity. This extensive and high-quality innovation portfolio underscores the

project's exceptional impact and its strong contribution to advancing V2X technologies, flexibility markets, and smart energy systems in Europe.

Therefore, this deliverable presents the consolidated implementation, outcomes, and impacts of the innovation management activities carried out within the EV4EU project, including a detailed assessment of Intellectual Property Rights (IPR) and exploitation-relevant results. Building on the innovation strategy originally defined in Deliverable D10.3 [1], this document reflects the full transition from strategic planning to concrete, validated, and exploitation-ready outcomes, capturing how innovation was systematically identified, managed, evaluated, and matured throughout the project lifecycle. In doing so, it documents the results of a robust and structured innovation management process that led to the development of 113 innovations across multiple countries, demonstrators, and stakeholder contexts. The document is structured as follows:

- Section 1 – Introduction presents the scope, objectives, and structure of the document, as well as its relationship with other EV4EU project deliverables.
- Section 2 – Innovation Management and Innovation Strategy reviews the applied concepts of innovation, innovation management, and innovation strategy, including the innovation funnel, types of innovation, and open innovation principles as implemented during the project.
- Section 3– EV4EU's Innovation Management Report describes the implemented innovation management process, including governance structures, roles, and collaborative mechanisms applied across the consortium.
- Section 4– EV4EU's Innovation Strategy and Innovation Portfolio Report presents the EV4EU innovation portfolio, including cross-country and cross-category analyses, innovation maturity, and the identification of cross-demo common innovations and KERs.
- Section 5– Intellectual Property Rights describes the applied IPR framework, ownership structures, protection measures, and patenting activities related to EV4EU results.
- Section 6 – Future Plans Regarding EV4EU's Innovation Portfolio outlines post-project development, scaling, exploitation intentions, and continued collaboration among partners. This section provides an overview of the defined innovation KPIs and a quantitative assessment of achieved results versus targets.
- Section 7 – Conclusions summarises the main results and achievements of the innovation management activities.
- APPENDIX - Appendix presents the detailed EV4EU innovation portfolios for each demonstration country (Denmark, Greece, Portugal, and Slovenia), providing comprehensive, innovation-level information supporting the analyses presented in the main body of the document.

Table of Contents

List of Figures

List of Tables

Acronym

ADMS	Advanced Distribution Management System
BESS	Battery Energy Storage System
BEV	Battery Electric Vehicles
BM	Business Model
BUC	Business Use Case
CSMS	Charging Stations Management System
CIM	Common Information Model
CPO	Charging Point Operator
CS	Charging Station
DER	Distributed Energy Resource
DR	Demand Response
DSO	Distribution System Operator
EC	Energy Community
eMPS	e-mobility Managed Service Provider
EMS	Energy Management Systems
ENTSO-E	European Network of Transmission System Operators for Electricity
ESS	Energy Storage Systems
ETS	Emissions Trading System
EU	European Union
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
EVT	Unified Entry Point
FCR	Frequency Containment Reserve
FFR	Fast Frequency Response
FMO	Flexibility Market Operator
GDPR	General Data Protection Regulation
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
ID	Identification Number
INESC ID	Instituto de Engenharia de Sistemas e Computadores - Investigação e Desenvolvimento em Lisboa
IRL	Innovation Readiness Level
KPI	Key Performance Indicators
LFM	Local Flexibility Market
LV	Low Voltage
MOL	Merit Order List
MV	Medium Voltage
PV	Photovoltaic
RES	Renewable Energy Sources
SoC	State of Charge
TRL	Technical Readiness Level
TLS	Traffic Light System
ToU	Time of Use
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

At the launch of the project, the consortium developed a comprehensive Innovation Strategy as part of WP10 – Dissemination, Communication and Innovation Management. This strategic document, initially presented in Deliverable 10.3 [1], defined the overarching approach to identifying, evaluating, and managing innovation across all project demonstrators. It also established a shared methodological framework to ensure consistency in innovation development, reporting and to support knowledge transfer among partners.

Throughout the project, the Innovation Strategy served not merely as a reference document but as an operational tool actively guiding innovation-related activity. Its implementation enabled the consortium to maintain a structured view of innovation potential, track progress continuously, and ensure that each demonstrator contributed to the project's innovation objectives.

To operationalize the strategy and systematically monitor innovation development, a series of Innovation Workshops were organized within Task 10.2. These workshops played a central role in project-wide innovation governance and were designed to:

- Facilitate structured reporting on innovation progress by each demonstrator.
- Support the identification of new innovation opportunities emerging during project implementation.
- Enable early detection of challenges and resource needs associated with innovation development.
- Exchange best practices, lessons learned, and methodological approaches between partners.
- Strengthen cross-demonstrator collaboration and generate synergies across technologies, use cases, and business models.
- Align innovation activities with other project work packages and with the overall innovation roadmap.

Workshops were conducted at regular intervals and were dynamically adapted as the project evolved. They became a key mechanism for ensuring transparency, strategic alignment, and coordinated innovation management. The interactive nature of the workshops encouraged knowledge-sharing and fostered a collaborative environment essential for progressing complex, multi-stakeholder innovation activities.

The systematic execution of the Innovation Strategy enabled each demonstrator to map its innovation trajectory, assess the maturity of its solutions, and identify steps required for further development, validation, or potential future market deployment. These activities also fed into the project's broader exploitation planning, ensuring a clear connection between technical achievements and their long-term innovation impact.

Deliverable 10.4 therefore does not only replicate the initial Innovation Strategy but also provides a detailed overview of its implementation throughout the project. In addition, it describes and analyses the key results and outcomes achieved through these activities, assessing their contribution to the project objectives. It highlights the processes, collaborative mechanisms, and structured activities carried out under WP10 that collectively supported effective innovation management and contributed to the project's overall innovation outcomes.

1.1 Scope and Objectives

The scope of this deliverable is to document, analyse, and consolidate the innovation management activities and results achieved within the EV4EU project. Building on the Innovation Strategy initially defined in Deliverable D10.3 [1], this document focuses on the practical implementation and outcomes of that strategy as applied across all work packages, demonstrators, and participating partners.

In particular, this deliverable provides a comprehensive overview of the innovation management process, including the identification, assessment, classification, and maturity evaluation of innovations developed during the project. It captures how innovative ideas were transformed into concrete outputs through a structured innovation funnel, open innovation principles, and continuous collaboration across a diverse, multi-actor consortium.

A key objective of this document is to present the consolidated EV4EU innovation portfolio, comprising technologies, digital tools, business models, and services developed and validated throughout the project. The deliverable analyses these innovations across multiple dimensions, including category, type, maturity (TRL and IRL), cross-demonstrator relevance, and linkage to Key Exploitable Results (KERs). In doing so, it provides transparency regarding the project's innovation capacity, internal coherence, and exploitation potential.

In addition, this deliverable addresses Intellectual Property Rights (IPR) aspects related to the developed innovations and KERs. It documents the applied IPR framework, ownership structures, protection mechanisms, and patent-related decisions, ensuring clarity and traceability of rights and responsibilities among partners and supporting sustainable post-project exploitation.

Finally, the document aims to establish a clear forward-looking perspective by outlining future plans for continued development, scaling, and exploitation of the EV4EU innovation portfolio beyond the project lifetime. By synthesising results, lessons learned, and best practices in innovation management, this deliverable serves both as a final record of achieved outcomes and as a reference framework for follow-up activities, future projects, and wider deployment of EV4EU solutions.

1.2 Structure

This deliverable is structured to provide a clear, logical, and comprehensive overview of the EV4EU innovation management framework, its implementation, and achieved results.

The document consists of seven main sections:

- Section 1 introduces the deliverable by defining its scope and objectives, describing its structure, and outlining its relationship with other project deliverables.
- Section 2 presents the theoretical and methodological background of innovation, innovation management, and innovation strategy, including the innovation funnel, types of innovation, and open innovation principles applied within the project.
- Section 3 describes the EV4EU innovation management process as implemented during the project, including governance structures, roles, tools, and collaborative mechanisms used across the consortium.
- Section 4 provides a detailed analysis of the EV4EU innovation strategy and innovation portfolio, including cross-country, cross-category, and maturity analyses, as well as the identification of common innovations and Key Exploitable Results (KERs).
- Section 5 focuses on Intellectual Property Rights (IPR), describing ownership structures, protection strategies, and patent-related activities associated with project results.
- Section 6 outlines future plans related to the EV4EU innovation portfolio, including post-project development, scaling, exploitation intentions, and continued collaboration among partners.

- Section 7 summarises the main conclusions derived from the innovation management activities.

Finally, the Appendix provides detailed innovation portfolios for each demonstration country (Denmark, Greece, Portugal, and Slovenia), serving as supporting material for the analyses presented in the main body of the document.

1.3 Relationship with other deliverables

This deliverable is closely linked to several other EV4EU project deliverables and builds upon the results and methodologies developed within Work Package WP10 – Knowledge Transfer, Dissemination and Innovation Management.

In particular, Deliverable D10.4 – Innovation Strategy: Update represents a continuation and consolidation of the Innovation Strategy initially defined in Deliverable D10.3 – Innovation Strategy. While D10.3 focused on establishing the innovation vision, governance framework, and methodological approach at the beginning of the project, D10.4 reports on the actual implementation, evolution, and concrete outcomes of this strategy throughout the project lifecycle.

Furthermore, this deliverable is directly connected to:

- D10.1 [2] – Plan for the Dissemination and Exploitation of Results including communication activities, as it provides structured input on innovation results, Key Exploitable Results (KERs), and exploitation potential that support dissemination and exploitation planning;
- D10.3 [1] – Innovation Strategy, by supplying validated innovation outcomes, ownership information, maturity assessments, and IPR considerations necessary for realistic and sustainable exploitation planning.

In addition, this deliverable is linked to all EV4EU technical, demonstration, and analysis deliverables in which innovations were identified, developed, validated, and described. Innovations reported in work package deliverables related to modelling, system architecture, tool development, demonstration implementation, marketability analysis, and lessons learned are systematically captured and consolidated in the EV4EU innovation inventory presented in this document. As such, D10.4 acts as a horizontal synthesis layer, integrating innovation-related results emerging across the entire project.

Overall, this deliverable functions as a central integration and consolidation point between research activities, demonstration results, innovation identification, IPR management, and exploitation planning. It ensures coherence, traceability, and consistency across EV4EU deliverables and provides a unified reference for innovation outcomes to be used both during the project and beyond its completion.

2 Innovation management and Innovation strategy

2.1 Innovation

Innovation refers to the introduction of new or improved ideas, products, services, or processes that create value for organizations and/or society. It encompasses both the development of novel solutions and their successful implementation and diffusion in practice. According to ISO 56000:2020, innovation is defined as “a new or changed entity realizing or redistributing value.” Common across definitions are the elements of newness, improvement, value creation, and the delivery of tangible benefits to relevant stakeholders.

Innovations do not need to be commercial. They may arise from new or improved products, services, organizational or business methods, strengthened networks or collaborations, advisory reports, or legislative changes - essentially anything that provides value or addresses a need. The impacts of innovation may be societal, research-related, environmental, technical, commercial, educational, or otherwise. These benefits do not need to be financial.

Innovation is related to but distinct from invention. An invention refers to a new idea or capability, while innovation involves applying that idea in practice to generate meaningful impact in a market or society. Not all innovations require an invention; many emerge from improvements to existing solutions or novel combinations of existing technologies, methods, or concepts.

In the energy and mobility sector, the EV4EU project (Electric Vehicles Management for Carbon Neutrality in Europe) provides a relevant example of innovation in practice. The project aims to advance V2X (vehicle-to-everything) technologies and accelerate the mass deployment of electric vehicles in Europe. According to the official project website, EV4EU defines its objectives, work packages, and demonstrators and highlights its strategic role in enabling large-scale V2X adoption through technical development, new business models, and policy support.

2.2 Innovation management

Innovation management is the process of taking innovative ideas from their inception to implementation. It refers to the systematic promotion of innovation within an organization and includes tasks such as planning, organizing, managing, and controlling innovation activities. As defined in ISO 56000:2020, innovation management can include establishing an innovation vision, strategy, policy, objectives, organizational structures, and innovation processes. These objectives can be achieved through structured planning, operational support, performance evaluation, and continuous improvement.

Innovation management encompasses all measures designed to promote innovation within an organization or consortium and to generate benefits, such as:

- Developing new products and services to access new markets;
- Improving existing products and services to strengthen competitive advantage;
- Enhancing internal processes to increase organizational efficiency or reduce costs;
- Creating new business models that open new revenue streams.

Effective innovation management is essential because it enables organizations to develop new ideas and procedures more quickly and effectively. This contributes to long-term sustainability and competitiveness through increased productivity, profitability, and flexibility. A key part of this process is defining the role of the innovation manager, who is responsible for coordinating innovation-related activities, including:

- Managing rights to use background knowledge during and after a project;
- Capturing and documenting innovation results;
- Assessing, protecting, and managing intellectual property (IP);
- Overseeing dissemination activities (informing stakeholders about results);
- Supporting exploitation activities (ensuring use of results);
- Facilitating market deployment of innovations.

Innovation management begins at the point of capturing creative or inventive outputs and concludes when a product or service is successfully deployed.

The principles of innovation management play a central role in the EV4EU project (Electric Vehicles Management for carbon neutrality in Europe), funded under the Horizon Europe programme. The project aims to accelerate the mass deployment of electric vehicles in Europe through advanced V2X (vehicle-to-everything) strategies and business models. EV4EU brings together partners across 4 countries to test and validate innovative V2X technologies in four real-life demonstration sites.

EV4EU's objectives include developing bottom-up, user-centric V2X management strategies and testing them in four demonstration environments to assess technological feasibility, business potential, and societal benefits. These strategies cover impacts on battery degradation, integration with power systems, interoperability, energy markets, and smart city transformations.

Innovation management within EV4EU ensures that newly developed tools, business models, technological concepts, and services follow a structured path - from ideation, to development and testing in demonstration sites, to dissemination and future exploitation. This includes the creation of interoperable platforms, V2X management stations, flexibility services, and digital tools for EV users.

In this context, innovation management ensures that EV4EU's technological and organizational innovations are systematically captured, evaluated, protected, disseminated, and prepared for future market deployment - aligned with the innovation management principles defined in ISO 56000.

2.3 Innovation strategy

Effective innovation management provides the structure that enables organizations and consortia to transform ideas into practical, valuable outcomes. According to ISO 56000:2020, innovation management involves establishing an innovation vision, strategy, policy, objectives, organizational structures, and supporting processes that guide innovation activities through planning, implementation, evaluation, and continual improvement. It ensures that intellectual property is assessed and protected, that results are captured, disseminated, and exploited, and that innovations move from conceptualization to deployment.

While innovation management provides the framework, it is the innovation strategy that guides the core decisions on how resources are allocated to meet innovation objectives, deliver value, and strengthen competitive or collaborative advantage. At its essence, a strategy represents concrete choices about what will be pursued, how, and why. Before an innovation strategy can be formed, three foundational steps must be taken:

- Starting with a real problem to solve – identifying challenges or opportunities that require innovative solutions.
- Being specific about possibilities – determining realistic innovation pathways and areas of potential impact.
- Identifying resources, capabilities, and supporting infrastructures – understanding the assets and competencies required to deliver innovation successfully.

A strong innovation strategy is built on a commitment to a coherent set of mutually reinforcing policies and behaviours that advance a specific goal. This includes analysing the competitive and technological environment, external challenges and opportunities, and the distinctive advantages of the organization or consortium. A well-defined innovation strategy brings several key benefits:

- Clarification of priorities and goals – enabling coordinated and focused innovation activities,
- Alignment among diverse groups – ensuring all stakeholders pursue shared objectives rather than fragmented initiatives;
- Long-term success and competitiveness – supporting organizations and partnerships in sustaining relevance, market position, and stakeholder engagement.

The importance of an innovation strategy is clearly reflected in the EV4EU project. The strategic orientation of EV4EU is shaped by its technological and market context: rapid growth of electric mobility, the need for smart and interoperable charging, and increasing requirements for flexible power systems. EV4EU focuses on bottom-up, user-centric V2X management strategies, taking into account impacts on batteries, energy networks, cities, energy markets, and user experience.

Developing and implementing an innovation strategy in EV4EU requires:

- Identifying real-world challenges such as limited V2X infrastructure, regulatory constraints, and operational complexities;
- Defining technological and organizational possibilities across diverse use cases and demonstration sites;
- Assessing partner capabilities, infrastructure readiness, user involvement, and system integration requirements.

Through its innovation strategy, EV4EU ensures alignment across partners, strengthens collaboration between technical, regulatory, and user-focused work packages, and supports structured innovation management activities. This strategic approach enables the consortium to focus on high-value opportunities and ensure that new technologies, business models, and services are developed systematically, validated in demonstration sites, and prepared for eventual market uptake.

2.4 The innovation funnel management process

Within the project, we implemented our innovation management process in alignment with the innovation funnel approach. The innovation funnel serves as a structured mechanism that enables a continuous stream of innovative ideas and prototypes to be collected, evaluated, and screened for viability. It is a simple yet highly effective concept that helps distinguish high-potential ideas from those that do not meet the required criteria.

At each stage of the funnel, ideas must pass through defined filters and decision gates. Those that meet the criteria advance to the next phase, while others are discontinued. The key objective of this approach is to generate a broad range of ideas relevant to the project context and to identify concepts that can contribute to net innovation value.

The innovation funnel management process (Figure 1) represents innovation as a phased progression consisting of:

- Idea generation – capturing a wide variety of potential concepts, opportunities, and solutions;
- Idea development – assessing feasibility, technical potential, added value, and preparing initial concept definitions;
- Diffusion – testing concepts for applicability, replicability, and alignment with project objectives;
- Scaling and dissemination of validated concepts – preparing the most promising concepts for further development, validation, or integration into project results.

This funnel-based approach provided a structured framework for ensuring that innovation activities across all project partners and demonstrators progressed in a systematic, transparent, and methodical way. Throughout the project, partners continuously captured innovative proposals, evaluated their feasibility, monitored development progress, and coordinated the adoption and further refinement of the strongest concepts.

Our innovation management process included:

- systematic collection and categorization of ideas from demonstrators;
- dedicated innovation workshops to share progress and refine concepts;
- evaluation of innovation potential and identification of high-value ideas;
- coordination of further development and testing of selected concepts,
- support for bringing concepts to a level suitable for broader dissemination, validation, or future deployment.

By applying the innovation funnel, we ensured a disciplined and consistent pathway for innovation - from initial idea capture, through development and assessment, to the final readiness of selected concepts for use within or beyond the project.

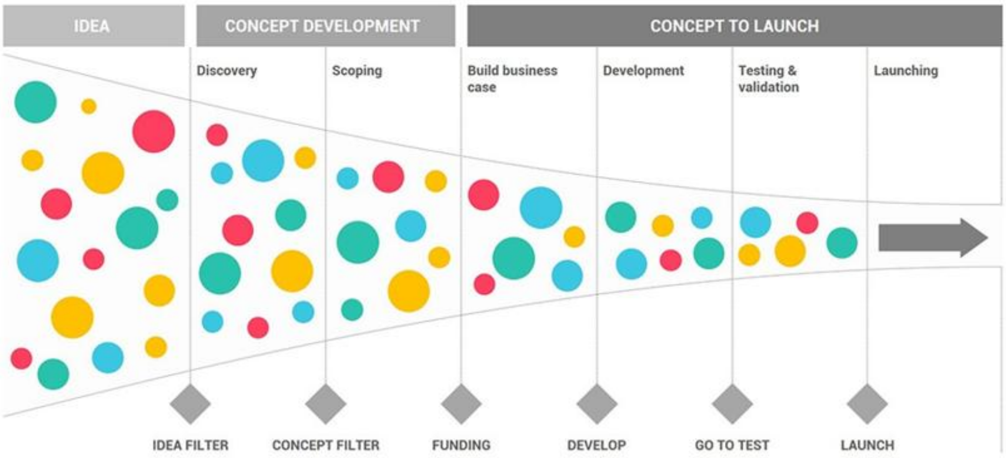


Figure 1: Innovation Funnel Management Process

2.5 Types of innovation

As part of the EV4EU project, a comprehensive analysis of all identified innovations was conducted in order to assess their characteristics, maturity, and potential impact. This assessment applied established innovation typologies and focused on two key dimensions: the degree to which the problem addressed by an innovation was defined, and the knowledge domain required to develop the corresponding solution. Based on these criteria, the project innovations were systematically classified into four distinct types: Sustaining innovations, Breakthrough innovations, Disruptive innovations and Basic innovations.

Sustaining innovations were identified as innovations addressing well-defined problems using established knowledge domains and proven technologies. Within EV4EU, these innovations focused on improving and refining existing products, services, or processes in order to strengthen current capabilities and performance. They were primarily developed through structured and iterative approaches such as research and development activities, incremental optimisation, and continuous improvement practices.

Breakthrough innovations represented solutions that applied new technologies or novel business models to significantly enhance or transform existing products, services, or processes. In the EV4EU project, these innovations aimed at step-change improvements and demonstrated strong potential for long-term impact on electric mobility, V2X ecosystems, and energy markets. Their development and adoption typically required longer timeframes and close collaboration among partners, making open and cross-disciplinary innovation approaches particularly effective.

Disruptive innovations were characterised by situations in which the problem was not fully defined at the outset, while the solution relied largely on existing competencies and expertise within the consortium. These innovations showed strong potential to reshape existing markets or create new value networks, potentially displacing incumbent solutions or actors. Within EV4EU, disruptive innovations were often developed through experimental, agile, and entrepreneurial approaches, enabling rapid learning and adaptation.

Basic innovations referred to exploratory research activities undertaken without a predefined problem or clearly specified application context. In the EV4EU project, basic innovations contributed to the generation of fundamental knowledge, early-stage concepts, and emerging technological insights. Although not immediately focused on deployment or market uptake, they strengthened the long-term innovation capacity of the consortium and provided a foundation for future applied and higher-maturity innovations.

This classification enabled a structured overview of the EV4EU innovation portfolio and demonstrated that the project delivered a balanced mix of innovation types. The results confirm that EV4EU did not focus solely on incremental improvements, but successfully generated sustaining, breakthrough, disruptive, and basic innovations, collectively supporting both short-term implementation and long-term transformation in the fields of electric mobility and energy systems.

We analysed all identified innovations within the project to understand their characteristics, maturity, and potential impact. As part of this assessment, we examined each innovation through the lens of established innovation typologies, focusing on the degree to which the problem was defined and the knowledge domain required to develop a solution.

2.6 Open innovation

Within the project, we applied selected elements of open innovation, based on the understanding that valuable knowledge and creative input can originate both inside and outside the consortium. By enabling the exchange of ideas and expertise with external stakeholders and among partners, open innovation supported broader engagement, improved insight generation, and more effective involvement of end users (Figure 2).

Compared to closed innovation approaches, open innovation allowed EV4EU to access a wider and more diverse pool of perspectives, which proved particularly valuable in early ideation phases and in understanding user behaviour. In addition, these approaches were cost-effective and well suited to the project's time and resource constraints.

In EV4EU, open-innovation-based approaches were used to:

- collect diverse inputs from project partners and external stakeholders;
- stimulate creativity during early innovation phases;
- enrich the innovation funnel with a broader set of ideas; and
- strengthen collaboration across demonstrators and work packages.

Overall, this approach ensured that innovation management activities benefited from both internal expertise and wider knowledge sources, supporting the project's innovation objectives and the quality of developed solutions.

Innovation strategy in EV4EU requires a thorough understanding of market, legal, social, and technical conditions in order to successfully transform innovative ideas into tangible value for all stakeholders.

Effective collaboration within a diverse partnership must therefore be built on a clearly defined strategic foundation consisting of three key elements: value exchange, clear role definition, and agreed terms and conditions governing cooperation. These elements are essential to fostering trust, transparency, and long-term collaboration within a European multi-partner project framework.

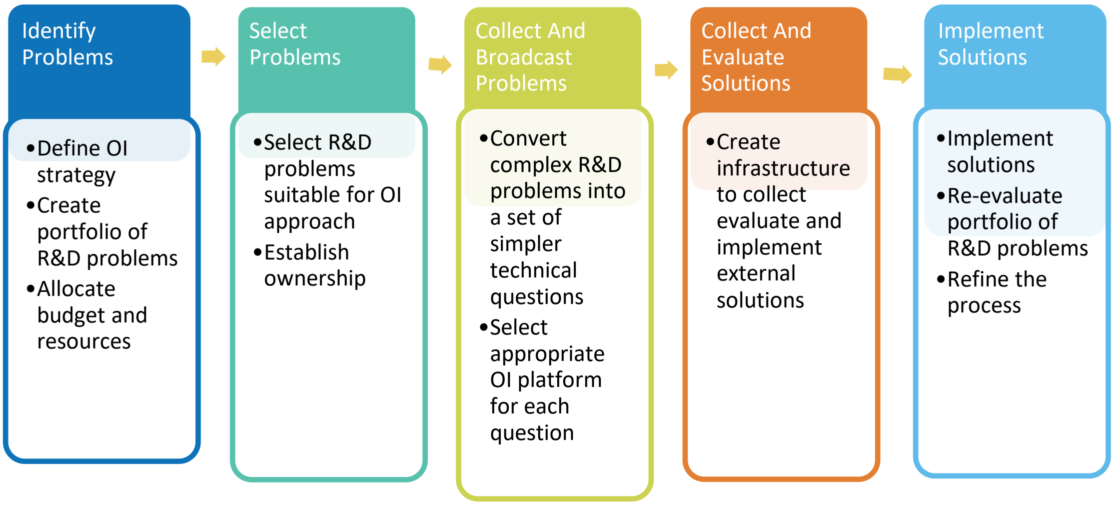


Figure 2: Five stages of open innovation process

These principles were consistently applied throughout the EV4EU project. Bringing together 16 project partners and 6 associated partners from four countries, EV4EU addresses the large-scale deployment of V2X technologies and user-centric solutions within a highly complex environment. This environment combines advanced technical development, regulatory and market considerations, active user engagement, and integration with the energy system.

Such complexity required a structured and systematic innovation strategy to ensure alignment among project objectives, transparency in cooperation, and coordinated progress across the consortium. Within EV4EU, the innovation strategy serves as a guiding framework that connects research and development activities with real-world demonstrations, validation in operational environments, and the preparation of results for further uptake, exploitation, and scaling at the European level. By doing so, it enables the project to effectively manage innovation processes and to translate technical advances into deployable, market-relevant solutions that support the transition towards carbon-neutral mobility and energy systems.

Within EV4EU, value exchange was realised through the open and transparent sharing of technical results, demonstration insights, user-related findings, and regulatory knowledge. This approach ensured that all partners benefited in accordance with their expertise, roles, and strategic interests, while maximizing the collective value created within the consortium.

Clear role definition enabled efficient and coordinated implementation across the project, with partners assuming responsibilities aligned with their competencies in development, system integration, analysis, dissemination, and demonstration activities.

The terms and conditions for collaboration were formally established through the Grant Agreement and Consortium Agreement, and further reinforced through continuous coordination within the innovation management framework. This combination ensured both stability and flexibility throughout the project lifecycle, allowing EV4EU to adapt to evolving technical, regulatory, and market conditions.

Overall, this structured and well-governed approach to collaboration supported effective partnership dynamics and contributed directly to the successful achievement of EV4EU's innovation objectives.

3 EV4EU's Innovation management report

The EV4EU partnership was structured as an integrated system of complementary functions. Strategic project management acted as the overall driver of the project, ensuring alignment with objectives and contractual commitments. Innovation management guided and steered the project, connecting strategic goals with technological and business innovation outcomes. Work packages and task management functioned as the engine room of the project, where concrete technical, organizational, and demonstration activities were implemented. Together, these elements formed a coherent framework that enabled the successful achievement of the EV4EU project objectives (Figure 3).

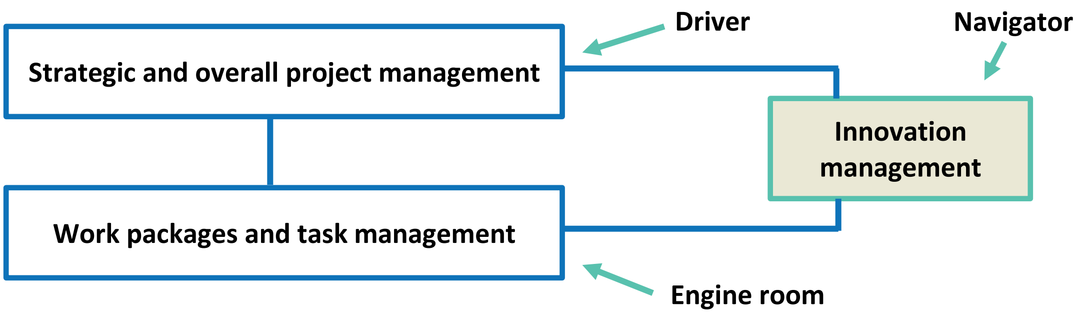


Figure 3: EV4EU Innovation management

Partners across the EV4EU consortium actively contributed to all parts of this structure. Collaboration was a core principle of the project, recognizing that no single partner could address the complex challenges of large-scale V2X deployment alone. By working in this collaborative manner, EV4EU successfully enabled:

- joint development of innovative solutions;
- improved cost efficiency through shared effort and resources;
- systematic sharing of knowledge and lessons learned;
- combination of diverse expertise and prior experience,
- integration of multiple perspectives, and
- validation across different use cases and demonstration contexts.

This collaborative approach proved essential for scaling innovation within EV4EU and ensured that innovation management activities were closely aligned with both strategic coordination and operational implementation throughout the project.

3.1 EV4EU's innovation management process

Innovation management within the EV4EU project was based on a clear understanding of market, legal, social, and technical aspects, with the objective of successfully implementing relevant and viable innovations (Figure 4). At an early-stage, the partnership established clear terminology, roles, agreements, and objectives, creating a common foundation for all subsequent activities and preventing ambiguities during project implementation.

A structured innovation management process was defined and applied throughout EV4EU to ensure coherence between research challenges, exploitation of results, and validation by potential users. Relevant stakeholders, both within and outside the consortium, were identified in collaboration with Task 10.1, while market developments were continuously monitored to support informed decision-making. Innovation KPIs were defined and assessed during the project, with progress reported through project management reports. In parallel, project results and associated intellectual property were systematically identified and monitored to support sustainable and realistic exploitation.

Innovation management activities were carried out by the Innovation Manager, Andreja Smole (GEN-I), in close cooperation with the Scientific Committee and project partners. This approach ensured alignment between strategic objectives and practical implementation, contributing to the effective delivery and validation of EV4EU innovation results.

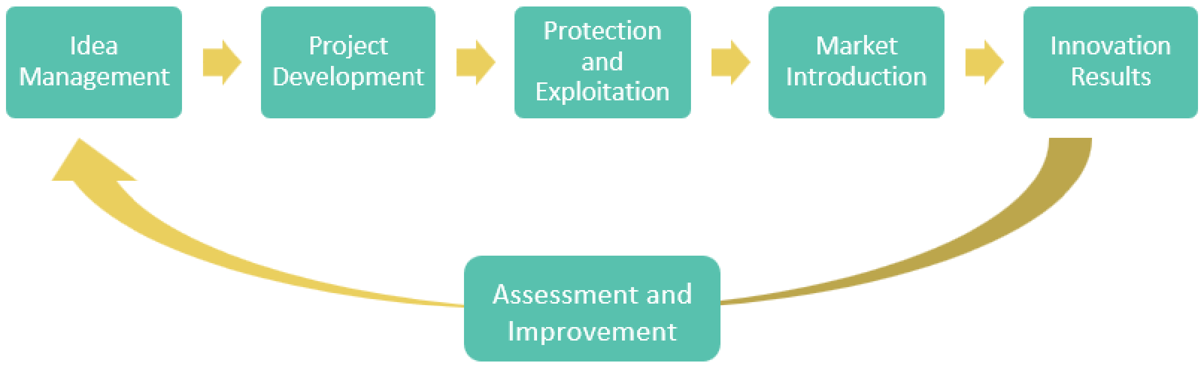


Figure 4: Innovation management EV4EU

The individual steps of the innovation management process applied within the EV4EU project, together with the key activities carried out at each stage, are described in detail in the following chapters of this document. The innovation management process itself is also illustrated in the Figure 4, which clearly demonstrates that it is a highly iterative and circular process, designed to enable continuous feedback, learning, and proactive refinement of innovations throughout the entire project lifecycle.

3.1.1 Diverse partnership and key objectives

The EV4EU project brought together a diverse set of academic and industrial partners with complementary expertise, competencies, and resources, including experience, skills, technologies, and infrastructure. This diversity enabled the generation of ideas from multiple perspectives and supported a deeper understanding of current and future market needs. During the project, the expectations and priorities of both individual partners and the consortium as a whole were identified and aligned.

This foundational step of the innovation strategy was addressed during the formation of the EV4EU partnership itself. From the outset, key project objectives were jointly defined and embedded into ambitious deliverables across all work packages. These objectives provided a clear strategic direction for the consortium, while additional intermediate targets were developed and refined throughout the project as part of ongoing implementation activities.

The structured and diverse partnership proved essential for effective collaboration and innovation, ensuring that the project was able to address complex challenges through shared knowledge, coordinated action, and aligned strategic goals. The Table 1 presents this important step in the innovation management process, together with the main activities and outcomes associated with it within the EV4EU project.

Table 1: Diverse partnership and key objectives

<table>
<tr><td>Objective
(Scope of the activity)</td><td colspan="3">Diverse consortium and defined key objectives</td></tr>
<tr><td>Inputs
(Inputs to the activity, and the persons/boards who provide them)</td><td colspan="3">• Shared expectations and priorities of individual partners;
• Creating consortium with different resources;
• Defined key objectives.</td></tr>
<tr><td rowspan="2">Actors
(Responsible: Main executor of the process; Consulted: Partners who provide information for the process; Informed: Partners kept informed of progress of the process)</td><td>Responsible</td><td>Consulted</td><td>Informed</td></tr>
<tr><td>• Coordinator (INESC ID – Instituto de Engenharia de Sistemas e Computadores - Investigação e Desenvolvimento em Lisboa)</td><td>• All partners</td><td>• Občina Krško
• Območna Obrtno-podjetniška zbornica Krško
• Regionalna razvojna agencija Posavje
• Nissan Motor Manufacturing
• Vestas Wind Systems A/S
• Associação Nacional de Transportadores Públicos Rodoviários Mercadorias</td></tr>
<tr><td>Actions
(List of the activities)</td><td colspan="3">• Meetings;
• Identification of EV4EU key objectives;
• Creating different documents, agreements, contracts;
• Defined WPs.</td></tr>
<tr><td>Outputs
(Description of outputs of this activity)</td><td colspan="3">Grant Agreement</td></tr>
<tr><td>Status</td><td colspan="3">Completed ✓</td></tr>
</table>

3.1.2 Defining terminology, roles, innovation process and objectives

A diverse partnership requires a shared understanding of innovation concepts, terminology, roles, and responsibilities. Within EV4EU, innovation management and the overall innovation strategy were presented and jointly adopted by the consortium at an early-stage of the project. Dedicated meetings and workshops were held to harmonize terminology, identify common objectives, and assign responsibilities related to innovation activities.

Under the leadership of the Innovation Manager, Andreja Smole (GEN-I), a joint review of the partnership strategy was carried out. During this process, the innovation management framework was defined, including the innovation process and the methods and techniques to be applied throughout the project. All partners participated in this process, were informed about the agreed approach, and confirmed their alignment with it.

Clear definition of responsibilities was a key factor for effective collaboration and achievement of project milestones. Work packages functioned as the operational core of the project, with WP leaders responsible for implementing activities and achieving intermediate objectives, supported by innovation management acting as a coordinating and guiding function. This structure ensured that the added value of innovation was clearly defined for individual partners, the consortium as a whole, and the wider ecosystem.

A clearly defined innovation process enabled structured project execution, while the application of appropriate methods facilitated efficient progress toward objectives. In particular, the innovation funnel approach was applied to manage innovations from idea generation through evaluation and development to validation, supporting a transparent and consistent innovation workflow across the project. The step is presented in Table 2.

Table 2: Defining terminology, roles, innovation process, and objectives

Objective **(Scope of the activity)**	Defined terminology, roles, innovation process and objectives		
Inputs **(Inputs to the activity, and the persons/boards who provide them)**	• Definition of the innovation concept and roles • Innovation strategy and management ideas		
Actors (Responsible: Main executor of the process; Consulted: Partners who provide information for the process; Informed: Partners kept informed of progress of the process)	**Responsible**	**Consulted**	**Informed**
	• Innovation manager (GEN-I d.o.o.) • Project Coordinator (INESC ID)	• All partners	• Not applicable
Actions **(List of the activities)**	• Meetings; • Workshop; • Creating documents.		
Outputs **(Description of outputs of this activity)**	• All partners have the same understanding of terminology, roles, innovation process and objectives • List of identified EV4EU deliverables with innovation potential		
Status	Completed ✓		

3.1.3 General plan and tool descriptions

The innovation management framework within EV4EU was implemented to operationalise the project's innovation strategy and support the systematic development of innovation results. The applied approach combined opportunity identification with internal validation through market insights and feedback from industrial, institutional, and user stakeholders. Validated opportunities were subsequently reflected in business-oriented and communication-related activities, ensuring consistency between innovation development, exploitation, and dissemination.

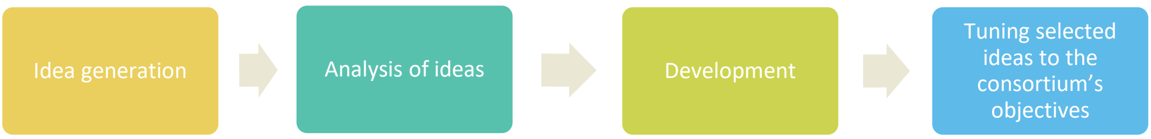


Figure 5: Schema of EV4EU Innovation Management framework

The innovation process within EV4EU followed a structured innovation funnel, covering idea generation, analysis, development, and alignment with consortium objectives. Idea generation was carried out after the consortium structure, roles, and objectives had been clearly defined. Through meetings, workshops, brainstorming sessions, and agile collaboration methods, partners generated a broad portfolio of ideas grounded in the project work plan, objectives, and deliverables. This phase expanded the consortium's shared knowledge base and provided the input for further evaluation.

In the idea analysis phase, generated ideas were systematically screened against consortium goals, assessed in terms of value creation, risks, feasibility, and readiness; and reviewed using indicators such as the Technology Readiness Level (TRL) and the Innovation Readiness Level (IRL). This process enabled the selection of the most promising ideas and supported early validation activities with relevant stakeholders and potential users.

Selected ideas then progressed to development, where they were transformed into concrete solutions within the relevant work packages and demonstrators. WP leaders were responsible for implementation and quality control, supported by innovation management and project coordination. Partners took responsibility for identifying, monitoring, and developing innovations resulting from their activities and collaborations, contributing to a balanced innovation portfolio aligned with project objectives.

Finally, innovations were aligned with consortium objectives and exploitation pathways, ensuring consistency with the strategic goals defined at project inception. Results from work packages were consolidated into exploitation-oriented outputs, further development, and post-project sustainability of EV4EU innovations.

This structured and fully implemented process ensured effective innovation management throughout EV4EU and enabled the successful transition from ideas to validated and exploitable project results.

The general innovation plan (Figure 5) describes the actions and/or steps to undertake within the EV4EU consortium in order to implement the innovation strategy. This innovation management plan tends to explore and scout new potential opportunities, and to internally validate them through market research and industrial/institutional stakeholder feedback. After their positive validation, these opportunities will be integrated in both Business and Communication plans.

3.1.3.1 Idea generation

Once the consortium's operations, working processes, roles, and objectives had been clearly defined, the project moved to the idea generation phase (Table 3). The objective of this first step of the innovation funnel was to collect a broad range of ideas in order to expand the consortium's knowledge base and solution space. Idea generation was supported by information gathering and market research, which provided valuable inputs. Given the continuous flow of ideas, they were systematically reviewed and assessed for their alignment with the project's objectives before progressing further in the innovation process.

Table 3: Idea generation

Objective **(Scope of the activity)**	Generating ideas		
Inputs **(Inputs to the activity, and the persons/boards who provide them)**	• EV4EU Work plan and resources review • EV4EU Objectives overview • EV4EU Deliverables overview		
Actors **(Responsible: Main executor of the process; Consulted: Partners who provide information for the process; Informed: Partners kept informed of progress of the process)**	**Responsible**	**Consulted**	**Informed**
	• Innovation manager (GEN-I d.o.o.) • Project Coordinator (INESC ID)	• All partners	• Not applicable
Actions **(List of the activities)**	• Meetings; Workshops; Brainstorming; Discussing; Other agile methods.		
Outputs (Description of outputs of this activity)	• List of ideas		
Status	Completed ✓		

3.1.3.2 Analysis of ideas

In this analysis phase of the innovation funnel (Table 4), the ideas generated during the previous idea-generation phase were systematically screened and evaluated. Each idea was assessed against the consortium's objectives to determine its added value for the project and the involved organizations. The evaluation considered expected benefits, risks, feasibility, and maturity, supported by indicators such as the TRL and the IRL. Initial validation activities with relevant users and stakeholders were also initiated during this phase.

Based on these assessments, priority was given to ideas with the strongest strategic relevance and implementation potential. Given limited resources, this phase ensured that efforts were focused on viable and impactful ideas that also positioned the consortium positively for future initiatives.

For each selected idea, key elements were defined and documented, including the idea description, value proposition, target beneficiaries, responsible and contributing partners, development status, exploitation responsibility within the consortium, and linkage to relevant project deliverables.

Table 4: Analysis of ideas

<table>
<tr><td>Objective
(Scope of the activity)</td><td colspan="3">Analysis of ideas</td></tr>
<tr><td>Inputs
(Inputs to the activity, and the persons/boards who provide them)</td><td colspan="3">• List of ideas from the previous step
• EV4EU Work plan and resources review
• EV4EU Objectives overview
• EV4EU Deliverables overview</td></tr>
<tr><td rowspan="2">Actors
(Responsible: Main executor of the process; Consulted: Partners who provide information for the process; Informed: Partners kept informed of progress of the process)</td><td>Responsible</td><td>Consulted</td><td>Informed</td></tr>
<tr><td>• Innovation manager (GEN-I d.o.o.)
• Project Coordinator (INESC ID)</td><td>• All partners</td><td>• Not applicable</td></tr>
<tr><td>Actions
(List of the activities)</td><td colspan="3">• Meetings;
• Workshops;
• Brainstorming;
• Discussing;
• Using different indicators (e.g., IRL: Innovation Readiness Level);
• Other agile methods.</td></tr>
<tr><td>Outputs
(Description of outputs of this activity)</td><td colspan="3">• Table with identified and analysed best ideas</td></tr>
<tr><td>Status</td><td colspan="3">Completed ✓</td></tr>
</table>

3.1.3.3 Development

In the development phase of the innovation funnel (Table 5), ideas that proved feasible, viable, and relevant were further developed into concrete solutions and, where applicable, prototypes. Development activities were carried out within the relevant work packages and demonstrators, in line with the project plan. WP leaders were responsible for overseeing implementation and ensuring quality control of results, supported by innovation management and project coordination. While the complexity and duration of development varied across innovations, a consistent development process was applied throughout the project.

The objective of this phase was not only to focus resources on ideas with the highest expected impact, but also to build a balanced portfolio of innovations aligned with the consortium's strategic objectives and future capabilities. Each partner was responsible for identifying, monitoring, and developing innovations resulting from their activities or collaborations, and for contributing to their long-term management in cooperation with the Innovation Manager and the Project Coordinator.

Table 5: Developing ideas

<table>
<tr><td>Objective
(Scope of the activity)</td><td colspan="3">Developing ideas</td></tr>
<tr><td>Inputs
(Inputs to the activity, and the persons/boards who provide them)</td><td colspan="3">• Identified innovations;
• Market analyses;
• Project specification;
• Project objectives.</td></tr>
<tr><td rowspan="2">Actors
(Responsible: Main executor of the process; Consulted: Partners who provide information for the process; Informed: Partners kept informed of progress of the process)</td><td>Responsible</td><td>Consulted</td><td>Actively involved</td></tr>
<tr><td>• WP leaders</td><td>• Innovation manager (GEN-I)
• Project Coordinator (INESC ID)</td><td>• All partners</td></tr>
<tr><td>Actions
(List of the activities)</td><td colspan="3">• Development within the WP;
• Additional activities to optimize the business opportunity of developed results:
    ○ Meetings;
    ○ Workshops;
    ○ Brainstorming;
    ○ Discussing;
    ○ Using different indicators (e.g., IRL: Innovation Readiness Level);
    ○ Other agile methods.</td></tr>
<tr><td>Outputs
(Description of outputs of this activity)</td><td colspan="3">• Developed identified innovations and prepared business plans</td></tr>
<tr><td>Status</td><td colspan="3">Completed ✓</td></tr>
</table>

3.1.3.4 Tuning selected ideas to the consortium's objectives

In the final phase of the innovation funnel (Table 6), selected innovations were aligned with the partnership's strategic objectives defined at the creation of the consortium. Initial evaluations and reviews of testing and validation activities were completed, and innovations that met technical, business, and user-related criteria were prepared for launch or further uptake beyond the project. Project partners took responsibility for the long-term stewardship of innovations resulting from EV4EU. This included defining post-project ownership, identifying responsible teams, and integrating innovation results into long-term strategies to ensure continuity, further development, and sustainable exploitation after the end of the project.

Table 6: EV4EU results and exploitation plan

<table>
<tr><td>Objective
(Scope of the activity)</td><td colspan="3">EV4EU results and exploitation plan</td></tr>
<tr><td>Inputs
(Inputs to the activity, and the persons/boards who provide them)</td><td colspan="3">• WP results
• Business plans
• Developers identified innovations</td></tr>
<tr><td rowspan="2">Actors
(Responsible: Main executor of the process; Consulted: Partners who provide information for the process; Informed: Partners kept informed of progress of the process)</td><td>Responsible</td><td>Consulted</td><td>Informed</td></tr>
<tr><td>• Innovation manager (GEN-I d.o.o.) Project Coordinator (INESC ID)</td><td>• All partners</td><td>• Not applicable</td></tr>
<tr><td>Actions
(List of the activities)</td><td colspan="3">• Meetings;
• Workshops;
• Brainstorming;
• Discussing;
• Using different indicators (e.g., IRL: Innovation Readiness Level);
• Other agile methods.</td></tr>
<tr><td>Outputs
(Description of outputs of this activity)</td><td colspan="3">• EV4EU objectives
• Exploitation plan of EV4EU results</td></tr>
<tr><td>Status</td><td colspan="3">Completed ✓</td></tr>
</table>

4 EV4EU's Innovation Strategy and Innovation Portfolio Report

Innovation plays a central and indispensable role across the entire EV4EU project, as it enables the development of advanced, scalable, and interoperable solutions that support large-scale electrification of transport, unlock new flexibility services, and transform electric vehicles into reliable and active resources for power system operation. Innovation in EV4EU is not limited to individual demonstrations, but is embedded throughout all work packages, use cases, and pilot sites, ensuring coherence between research, technological development, market integration, and real-world deployment.

According to EV4EU's internal innovation management framework, innovation is essential for creating new products and services, improving and adapting existing solutions, optimizing processes, and developing new business models that open additional value streams for consortium partners. These innovation activities are strategically coordinated through clearly defined innovation objectives, processes, and governance structures, allowing partners to address emerging technological, regulatory, and market challenges in a consistent and forward-looking manner. This structured approach supports the effective integration of EVs into electricity markets, grid services, and sector-coupling scenarios across different European contexts.

Across all project demonstrators, innovation is a key enabler for V2X management, participation in multiple energy and flexibility markets, and interaction between EVs, EV users, aggregators, DSOs, and TSOs. Cutting-edge use cases developed within EV4EU rely on new probabilistic and data-driven algorithms, interoperability solutions, aggregation methodologies, and advanced control frameworks. Together, these innovations allow EVs - and complementary assets such as battery energy storage systems (BESS) used as EV equivalents - to deliver reliable, fast, and scalable flexibility services under diverse operational and regulatory conditions.

The project's structured innovation strategy, coordinated within WP10 and regularly discussed among partners, ensures alignment of innovation efforts across technical, commercial, and regulatory dimensions. This approach clarifies priorities, supports risk management, and strengthens collaboration between partners with different expertise and roles within the value chain. As a result, innovative outcomes in EV4EU are not developed in isolation, but are systematically embedded into the project's broader objectives of carbon neutrality, grid optimization, energy market participation, and scalability.

Through this project-wide and coordinated innovation approach, EV4EU ensures that its results are robust, transferable, and prepared for sustainable exploitation beyond the project duration, contributing to Europe's long-term energy transition and electrified mobility ecosystem.

The analysis of innovations at the EV4EU project level shows a mature, well-structured portfolio of technological and methodological advancements that collectively strengthen the project's capacity to enable large-scale integration of electric vehicles and flexibility services across Europe. Innovations span advanced technologies, forecasting tools, system functionalities, optimization algorithms, demand-response mechanisms, and virtual power plant integration, each positioned within specific work packages and demonstrator environments. Together, they form a coherent innovation ecosystem that supports both technical excellence and strategic exploitation.

Across the project consortium, innovations operate at varying Technology Readiness Levels (TRL 5–8) and Innovation Readiness Levels (IRL 4–8), demonstrating a balanced progress trajectory from fundamental methods to near-commercial solutions. Many of the most impactful innovations have reached TRL/IRL 8, indicating they are ready for practical deployment in utility environments.

The portfolio also shows strong alignment with the EV4EU innovation strategy, which emphasizes structured innovation management, cross-partner collaboration, IP protection, and the continuous monitoring of innovation KPIs. This framework ensures that new ideas progress through the full innovation funnel - from ideation to market introduction - while securing the intellectual property needed for long-term exploitation.

Innovation within complex research and innovation projects plays a central role in transforming scientific and technical knowledge into tangible value for society, markets, and policy. In the context of modern energy and mobility systems, innovation is not limited to technological advancement, but also encompasses services, processes, business models, governance approaches, and user engagement methods.

Innovations emerge as a response to evolving challenges in energy transition, digitalisation, and mobility systems. They are driven by a combination of regulatory pressure, market needs, technological progress, and societal expectations. Within a project-driven environment, innovation acts as a bridge between research and implementation, ensuring that project results move beyond conceptual development toward practical applicability.

Innovations are also a key mechanism for ensuring that project outcomes remain relevant under changing external conditions. As markets, technologies, and policy frameworks evolve, innovation allows project results to adapt, scale, and remain resilient. This highlights the importance of managing innovations as a continuous and adaptive process, rather than a one-off activity.

Innovations developed within the EV4EU project exhibit several characteristic features that are typical for research and innovation initiatives in the field of electromobility and connected energy–transport systems:

- Multi-disciplinarity: EV4EU innovations integrate technological, economic, social, and regulatory aspects. They span across electromobility, smart energy systems, digital solutions, user behaviour, and policy frameworks, reflecting the complexity of real-world e-mobility ecosystems.
- Incremental and radical elements: The project combines incremental improvements of existing e-mobility solutions (e.g., optimisation of charging strategies or system interoperability) with more radical innovations, such as advanced V2X concepts, new business models, and novel governance approaches.
- Strong stakeholder interdependence: The success of EV4EU innovations relies on close collaboration between multiple stakeholders, including cities, energy providers, mobility operators, technology providers, public authorities, researchers, and end users. Demonstration activities in living labs and pilot sites are a core mechanism for aligning these actors.
- Uncertainty and risk: As many EV4EU solutions are tested in real-life conditions for the first time, they face uncertainties related to technical performance, user acceptance, scalability, and regulatory compatibility. These uncertainties are an inherent part of innovation in emerging e-mobility systems.

Given these characteristics, innovations within EV4EU do not follow a linear or purely sequential development path. Instead, they evolve through iterative cycles of design, implementation, validation, and feedback, drawing directly on insights from pilot deployments and stakeholder engagement.

Within EV4EU, innovations progress through different levels of maturity, from early-stage concepts and prototypes to validated solutions demonstrated in operational environments. Throughout this process, both the problem definition and the understanding of feasible solution spaces become increasingly refined. This evolutionary approach enables innovations to transition from exploratory or experimental concepts toward more applied, scalable, and potentially replicable solutions suitable for wider European uptake.

Such a dynamic perspective is essential for understanding the impact of EV4EU innovations. Early-stage developments may not immediately deliver measurable impacts but play a critical role in building knowledge, trust, and learning capacities among stakeholders. These foundations are crucial for later high-impact outcomes. Conversely, more mature innovations demonstrated within the project can deliver tangible short- and medium-term value, while remaining firmly rooted in long-term research and systemic learning processes fostered by EV4EU.The impact of innovations can be assessed across several dimensions:

- Technical impact, through improved system performance, reliability, or efficiency;
- Economic impact, through new services, business models, cost reductions, or market opportunities;
- Societal impact, by supporting sustainability goals, user empowerment, and behavioural change;
- Policy and regulatory impact, by informing decision-makers and enabling evidence-based regulation.

Importantly, the impact of innovation is not fully immediate nor always directly measurable. In many cases, innovation impact emerges gradually over time, through further development, replication, scaling, and integration into wider systems and markets. Consequently, the outcomes of EV4EU should be understood as part of a longer-term innovation trajectory, where several results will continue to mature and materialise beyond the project duration. As a result, EV4EU partners envisage continued development and evolution of the project innovations after the end of the project, building on the knowledge, pilots, and stakeholder networks established during the project lifetime.
Within the EV4EU project, innovations should be understood as dynamic and evolving assets that contribute both to short-term project objectives and to longer-term strategic and systemic transformation of electromobility and energy–transport integration. Their impact is therefore not fully immediate nor confined to the project lifetime. A robust innovation analysis in EV4EU goes beyond assessing what innovations deliver during the project and focuses on how they position the project and its partners for future developments, continued learning, replication, and sustained impact beyond the project duration.

At the operational level, innovations cover several categories, including technologies, tools, services, and decision-support mechanisms. They address concrete system needs such as variable grid tariffs, routing and charging optimization, demand forecasting, V2G/V2X market participation, and flexibility activation, supporting both DSOs and aggregators. Many are tied to real demonstrators where regulatory, technical, and market conditions shape robust, replicable use cases.

Importantly, the analysis highlights the multi-country, multi-actor nature of EV4EU: innovations stem from DSOs, universities, research institutions, utilities, and technology providers. This diversity ensures broad applicability and leverages complementary strengths: technical expertise, market insight, and system-operation experience, to achieve scalable and cost-efficient solutions.

Overall, the project demonstrates a high degree of innovation maturity, a clear exploitation pathway, and strong internal consistency between the strategic innovation framework and the concrete technologies being developed. This positions EV4EU to deliver not only scientific and technical advances, but also operational tools and market-ready solutions that support Europe’s transition toward an integrated, flexible, and electrified energy system.

4.1 EV4EU's Innovation portfolio

Based on the innovation inventory compiled at the end of the EV4EU project, the consortium developed and documented a total of 113 innovations. Each of these innovations represents a distinct outcome of project activities and is therefore treated as a unique innovation.

The EV4EU innovation portfolio shows a diverse innovation across the four demonstration countries- Slovenia (SLO), Greece (GR), Denmark (DK) and Portugal (PT). Each demo contributes a distinct mix of tools, technologies and business-model innovations, but their quantitative contribution varies significantly.

Table 7: Number of Innovations by Country

Country (Demo Site)	Number of Innovations
Slovenia (SLO)	48
Greece (GR)	27
Portugal (PT)	20
Denmark (DK)	18
Total	**113**

The EV4EU innovation portfolio reflects the project's strong focus on real-world demonstration, system integration, and market-oriented deployment of V2X and e-mobility solutions. In total, the portfolio comprises 113 innovation entries developed and validated across the four participating demonstration countries. The distribution of innovations across countries is not uniform but mirrors the scale, scope, and complexity of the implemented pilot activities. Slovenia accounts for the highest number of innovation entries, followed by Greece, Portugal, and Denmark. This distribution highlights the differentiated roles of national demonstrations within EV4EU and confirms that innovation output is closely linked to the intensity and breadth of local pilot implementations rather than to a prescriptive target per country.

Table 8: Consortium-level innovation portfolio summary (N = 113)

Section	Metric / Breakdown	Value
Size	Total number of innovations (entries)	**113**
Maturity (TRL)	Average TRL	**6.70**
	Median TRL	**7.00**
Maturity (IRL)	Average IRL	**6.95**
	Median IRL	**7.00**
Category distribution	Tools	**60**
	Technologies	**23**
	Business Models and Services	**30**
Innovation type distribution	Breakthrough innovation	**82**
	Disruptive innovation	**20**
	Sustaining innovation	**9**
	Basic innovation	**2**

From a structural perspective, the portfolio is dominated by digital and system-level solutions. Tools represent the largest category of innovations, forming the backbone of the EV4EU ecosystem by enabling monitoring, control, optimisation, forecasting, and decision support. These tools are complemented by a substantial set of Business Models and Services, which translate technical capabilities into operational, commercial, and regulatory solutions such as flexibility services, green charging schemes, demand response mechanisms, and aggregation models. Technologies, including V2X charging stations, communication modules, monitoring devices, and energy management systems, complete the portfolio by providing the physical and software infrastructure required for implementation. Together, these categories illustrate that EV4EU innovations are designed as integrated socio-technical solutions rather than isolated technological components.

A closer look at innovation focus areas reveals that most solutions are operation-focused, supporting real-time system management, interoperability, and integration with distribution grids and market platforms. Decision-focused innovations form the second largest group and include planning tools, co-simulation platforms, forecasting algorithms, and decision support systems for DSOs, aggregators, and CPOs. In parallel, a significant share of innovations targets grid services and EV-focused use cases, underscoring the project's ambition to position EVs as active, bidirectional assets capable of delivering flexibility and supporting grid stability. User-focused services, while smaller in number, play a critical role in enabling acceptance and engagement, addressing EV user behaviour, interfaces, and incentive mechanisms.

In terms of innovation typology, the EV4EU portfolio is predominantly composed of breakthrough innovations. These innovations build on existing technologies and knowledge but extend them substantially through new combinations, system integrations, and operational concepts tailored to real deployment environments. Disruptive innovations form a smaller but strategically important share of the portfolio, particularly in areas related to local flexibility markets, new contractual arrangements, and the integration of V2X into distribution system operations. Sustaining and basic innovations complete the portfolio by refining existing solutions and providing foundational components that support more advanced developments.

The maturity of the innovation portfolio strongly reflects EV4EU's demonstrator-driven approach. Most innovations are positioned at medium to high Technology Readiness Levels, with a large concentration at TRL 7 and 8, indicating validation and demonstration in relevant operational environments. Innovation Readiness Levels follow a similar pattern, confirming that many solutions are not only technically mature but also sufficiently developed from organisational, market, and stakeholder perspectives. At the same time, the presence of innovations at lower TRL and IRL levels highlights the project's role in creating a pipeline of emerging solutions that can evolve further beyond the project duration.

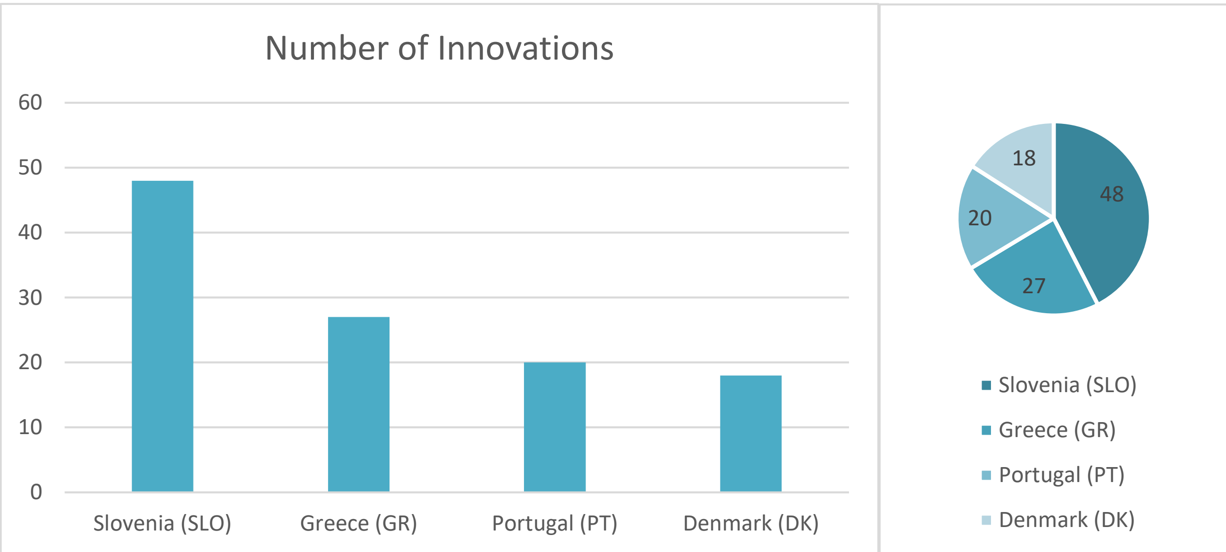
Finally, the distribution of innovations across work packages shows a clear concentration in the demonstration-oriented parts of the project. The majority of innovations are linked to work packages responsible for pilot deployment, system integration, and operational validation, while earlier work packages contribute analytical, modelling, and user-centric innovations that feed into later stages. This structure confirms that the EV4EU innovation portfolio is coherent, cumulative, and explicitly designed to support long-term exploitation, replication, and scaling of results beyond the lifetime of the project.

Overall, the innovation inventory confirms that EV4EU successfully translated its innovation strategy into concrete outcomes. The 113 innovations documented in the table are the result of sustained collaborative work, effective coordination across work packages, and continuous alignment with demonstrator needs. The progress achieved demonstrates that the project has established a strong foundation of mature, context-specific, and transferable innovations with clear potential for further development, uptake, and exploitation beyond the project lifetime.

4.1.1 Cross-country Interpretation and Country deep dives

The distribution of innovation entries across the participating countries reflects differences in both the scale and the nature of the demonstration activities implemented within the EV4EU project. As shown in Table 7 and Figure 6, Slovenia accounts for the highest number of recorded innovation entries (48), which is primarily linked to the breadth of pilot activities and the comprehensive scope of system-level demonstrations implemented. This is followed by Greece with 27 innovation entries, Portugal with 20, and Denmark with 18, each reflecting the specific focus, maturity, and intensity of their respective national demonstration setups within the project. This distribution is primarily driven by the type and scope of demonstrators implemented in each country, as national pilots addressed different segments of the V2X ecosystem. Countries hosting large-scale, system-level, and multi-actor demonstrators naturally generated a higher number of innovation entries, while countries focusing on more specialised or technology-specific demonstrators reported a lower, yet highly targeted, number of innovations. As such, the observed distribution reflects structural project design choices and demonstrator setup, rather than differences in innovation capacity or the level of contribution among participating countries.

Figure 6: Number of Innovations by Country



The innovation inventory reflects the full breadth of innovation work carried out across the project and demonstrates the effectiveness of the EV4EU innovation management approach in capturing and consolidating results from a highly distributed and multi-actor consortium. Innovations range from digital tools and software platforms to technological solutions and business models, covering key aspects of V2X integration, grid operation, flexibility management, user engagement, and market mechanisms. This diversity highlights the project's ability to address complex system-level challenges through parallel and complementary innovation efforts.

The distribution of innovations across demonstration countries further illustrates the project's progress and structure. Innovations were produced in all participating countries, reflecting the diversity of national demonstrators and their specific focus areas. Countries hosting larger, system-level and multi-actor demonstrators generated a broader set of innovations, while countries with more specialised demonstrators contributed a smaller but highly focused portfolio of results. This pattern reflects deliberate project design choices and the tailored objectives of each demonstrator, rather than differences in innovation capability or engagement. This distribution should be interpreted as an outcome of how the national demonstrators were set up and what each demonstration environment prioritized, rather than as a proxy for the quality of contributions.

A meaningful cross-country comparison therefore starts with the observation that the inventory captures innovations spanning multiple categories and types, which allows differences in national emphasis to be quantified. Across the full portfolio, innovations are classified primarily as Tools (60), followed by Business Models and Services (30), and Technologies (23).

In parallel, the innovation type tagging shows a strong orientation toward high-impact developments, with Breakthrough innovations representing the majority of entries (82), followed by Disruptive (20), Sustaining (9), and Basic (2).

These portfolio-level patterns matter for cross-country interpretation because national demonstrators that concentrate on operational integration and platform functionality typically yield more tool-oriented innovations, while demonstrators that focus on infrastructure and device-level developments tend to contribute relatively more technology-oriented results. The table's categorisation fields (Category, Sub-category, Innovation type) are precisely what enable this kind of structural explanation.

A second essential lens for cross-country interpretation is maturity, because it distinguishes "how many" innovations from "how close to deployment" the innovations are. The inventory reports Technology Readiness Level (TRL) for all entries with an average TRL of about 6.7 and a median of 7.0, while Innovation Readiness Level (IRL) is available for all entries with an average of about 7.0 and a median of 7. The maturity profile supports a cross-country reading that the project's innovation activity is not limited to conceptual exploration; rather, the portfolio as recorded in the table is largely positioned around demonstration and integration stages, which is consistent with the table's role as an end-of-project innovation inventory.

Because work packages represent different kinds of development activity, cross-country differences in innovation counts can be interpreted through where demonstrator activities concentrated along the project pipeline (for example, integration and operational demonstrators versus more specialised technical pilots). The WP field therefore offers a grounded, data-driven way to explain country-level variation without introducing speculation about non-observed factors.

Finally, a careful cross-country interpretation benefits from explicitly recognising that the table encodes context through multiple fields beyond country alone - particularly Owner/Leader(s), involved entities, and ownership/IP maturity descriptions. Even when innovation themes appear similar across countries, the inventory distinguishes innovations by the organisational lead, demonstration site, maturity, and category framing, which is consistent with interpretation that innovations are unique because they were developed by different groups and in different demo contexts.

A cross-country interpretation based on the innovation inventory confirms a clear differentiation in national innovation profiles that reflects the focus of each demonstration environment. Slovenia emerges as the main contributor of system-level tools and market-oriented solutions, with a strong concentration of innovations related to platforms, decision-support tools, flexibility market integration, VPP functionality, and end-to-end system deployment. Greece shows a pronounced strength in algorithms and operational intelligence, as evidenced by numerous innovations related to tariff calculation, forecasting methods, transformer and LV monitoring, real-time triggering mechanisms, and operational Decision Support Systems, indicating a focus on grid observability and real-time control. Portugal presents a more balanced innovation profile, combining technological developments with service- and user-oriented innovations, including EV fleet management services, user engagement tools, and market-relevant V2X participation mechanisms, which together indicate a strong orientation toward usability and market interaction. Denmark anchors the portfolio through hardware-focused and embedded system innovations, including charging station design, firmware, PCB and hardware components, energy management systems, and load-balancing technologies, reflecting its emphasis on robust infrastructure and device-level integration. Overall, the country-specific patterns observed in the table are consistent and derive directly from the type, category, and maturity of innovations reported for each demonstration site.

Across all demonstrators, the distribution of innovation types reveals distinct national innovation profiles shaped by the scope and objectives of the implemented pilots. Slovenia and Greece place a strong emphasis on operational and decision support tools, reflecting their focus on real time system integration, market activation, and grid operation. Denmark anchors its contributions primarily in hardware development and control algorithms, providing technologically mature solutions at the charging infrastructure and edge control level. Portugal, in contrast, concentrates on system modelling, green charging concepts, and regulatory or behavioural insights, supporting planning, validation, and user centred decision making. These profiles are largely complementary rather than overlapping, resulting in a cross-demonstrator innovation landscape in which each country addresses a distinct structural layer of the EV4EU ecosystem.

In reporting terms, the strongest and most defensible conclusion from the table is therefore that cross-country differences reflect the demonstrator scope and the mix of activities implemented in each national context, while the portfolio as a whole demonstrates a mature, implementation-oriented innovation outcome, evidenced by the concentration of TRL/IRL values in the 7–8 range and the predominance of breakthrough-typed innovations.

In summary, the quantitative distribution of innovations across demonstrators should not be interpreted merely as a measure of volume. Instead, it reflects the strategic specialisation of each national demonstrator. Slovenia leads in system integration and market activation, Greece in grid and V2X operational intelligence, Denmark in hardware and smart charging edge technologies, and Portugal in modelling driven and user centric innovation. Together, these contributions form a balanced and interdependent innovation architecture that supports the large-scale deployment of V2X solutions across Europe.

The innovation inventory further indicates that contributions are concentrated among a core group of organisations that are repeatedly listed as owners or leaders of innovations across different demonstrators and work packages. In particular, GEN-I, INESC-ID, Circle, DTU, HEDNO, and PPC appear frequently as leading entities, reflecting their central role in the development of technological components, digital tools, and market-oriented solutions within the project.

A total of 113 innovations are recorded in the EV4EU innovation inventory. The country-level distribution shows that Slovenia contributes the largest share of the portfolio, with 48 innovations, followed by Greece with 27, Portugal with 20, and Denmark with 18. This distribution reflects the scope and structure of the national demonstrators, with Slovenia hosting a broad, system-level and multi-actor demonstration environment that naturally generated a higher number of distinct innovation outcomes.

Across all demonstrators, the distribution of innovation types reveals clear national innovation profiles shaped by the scope and objectives of the implemented pilots. Slovenia and Greece predominantly emphasise operational and decision-support tools; Denmark anchors the project with hardware-centric and edge-control technologies; and Portugal focuses on system modelling, green charging, and regulatory or behavioural insights. These profiles are complementary rather than overlapping, resulting in a cross-demonstrator innovation landscape in which each country addresses a specific structural layer of the EV4EU ecosystem.

In summary, the quantitative distribution of innovations across demonstrators should not be interpreted solely as a measure of volume. Instead, it reflects the strategic specialisation and demonstrator typology chosen in each country. Slovenia leads in system integration and market activation, Greece in grid and V2X operational intelligence, Denmark in hardware and smart-charging edge technologies, and Portugal in modelling-driven and user-centric innovation. Together, these contributions form a balanced and interdependent innovation architecture supporting the large-scale deployment of V2X solutions across Europe.

4.1.1.1 Danish Demonstrator

The Danish demonstrator takes a strongly operational and experience-driven approach, focusing on real-world testing and validation of EV charging infrastructure in a live environment. The demonstrator provides a physical setting where charging technologies, user interaction, and system performance can be observed and evaluated. Rather than prioritising extensive algorithmic or modelling development, the Danish demonstrator delivers hands-on validation of charging hardware, firmware, backend systems, and site-level operation. This enables valuable insight into charger behaviour, control logics, local constraints, and user-experience aspects that cannot be fully captured through simulation or laboratory testing.

As such, the Danish demonstrator plays a complementary and enabling role within the overall EV4EU project. It acts as a physical validation platform that connects the theoretical, algorithmic, and system-level innovations developed in other work packages with real-world operational performance. By anchoring digital and market-oriented concepts to tangible infrastructure behaviour, the Danish demo helps ensure that project solutions remain technically feasible, reliable, and deployable under practical conditions.

From an innovation portfolio perspective, Denmark contributes 18 innovations, characterised by a clear technology- and infrastructure-driven profile. Tools account for 11 innovations, primarily covering charger control systems, monitoring solutions, firmware, backend platforms, and edge-level operational intelligence. These tools strengthen the control and observability layer of charging infrastructure and support reliable field operation. Technologies (3 innovations) are focused on EV charging hardware, grid-connected assets, and physical infrastructure components, while Business Models and Services (4 innovations) relate mainly to local flexibility provision and charging-service concepts.

The Danish Innovation Portfolio, comprising all identified innovations together with their key information (such as the innovation title, short description, maturity level, involved stakeholders, and relevant technical and business aspects), is compiled and presented in the Appendix 9.1 - Innovation portfolio – Denmark. The appendix serves as a consolidated reference, providing a structured overview of the Denmark innovations and supporting further analysis within the broader project context.

Denmark contributes a smaller but highly specialised innovation portfolio, clearly shaped by its operational and hardware-driven demonstrator design. Denmark's innovations are centred on charging infrastructure, firmware and PCB design, CAD layouts, charger control, backend systems, and load-management solutions. These contributions position the Danish demonstrator as the hardware and charger-technology backbone of the project. While Denmark contributes fewer innovations in absolute terms compared to larger system-level demonstrators, the innovations it delivers are typically highly specialised and technically mature.

Overall, Denmark contributes highly specialised, infrastructure-focused innovations that reinforce the physical and control layers of the EV4EU ecosystem. While the Danish portfolio is smaller in absolute volume compared to large system-integration demonstrators, its contributions are critical for grounding project results in operational reality. By validating charging technologies, control mechanisms, and user interaction in live conditions, the Danish demonstrator strengthens the robustness and real-world applicability of EV4EU solutions.

4.1.1.2 Greek Demonstrator

The Greek demonstrator focuses on the development and validation of advanced analytical tools and decision-support mechanisms that enable the scalable and intelligent integration of EV charging infrastructure into distribution networks. The Greek innovation portfolio is strongly centred on forecasting, behavioural modelling, monitoring, and optimisation algorithms, providing DSOs and CPOs with deeper insight into user behaviour, network conditions, and system-level requirements.

A central pillar of the Greek demonstrator is the modelling of EV user charging behaviour, which delivers predictive insights into charging demand, temporal patterns, and spatial distribution. This modelling capability is fundamental for both real-time operational planning and long-term grid and infrastructure development. Closely related are algorithms for the calculation of variable grid tariffs, which introduce dynamic pricing schemes aimed at improving distribution grid operation while incentivising users to adapt charging behaviour in a system-friendly manner. These innovations represent a significant step toward incentive-based demand shaping in smart distribution grids.

The Greek demonstrator further delivers a comprehensive set of tools for time estimation for routing and charging, allowing EV users and CPOs to optimise journeys and charging sessions based on network capacity, expected demand, and operational constraints. These functionalities are complemented by day-ahead demand forecasting models developed for individual EV charging points, employing advanced machine-learning techniques such as LSTM, ARIMA, and XGBoost. Together, these tools enable DSOs to anticipate congestion and flexibility requirements, while supporting CPOs in more accurate planning and capacity management.

In addition to planning and forecasting, the Greek demonstrator places strong emphasis on operational intelligence. Innovations include transformer and low-voltage (LV) monitoring solutions, real-time operational triggering mechanisms, and advanced V2X platform functionalities such as real-time notifications, V2G interfaces, and forecast-based activation workflows. These developments significantly enhance the operational capability of the Greek ecosystem, enabling responsive and data-driven management within the HEDNO and PPC environments.

Overall, Greece contributes 27 innovations, making it the second-largest contributor within the EV4EU project. The Greek innovation profile is clearly tool-centric, with 18 tools-based innovations dominating the portfolio. These tools primarily address algorithms, monitoring and control systems, and decision-support functionalities for DSOs, CPOs, and aggregators. A smaller but relevant group of technology-oriented innovations (5) supports grid monitoring and interoperability, while Business Models and Services (4) play a complementary role.

The Greek Innovation Portfolio, comprising all identified innovations together with their key information (such as the innovation title, short description, maturity level, involved stakeholders, and relevant technical and business aspects), is compiled and presented in the Appendix 9.2 - Innovation portfolio – Greece. The appendix serves as a consolidated reference, providing a structured overview of the Greece innovations and supporting further analysis within the broader project context.

Greece contributes a focused set of innovations oriented toward grid intelligence and operational analytics. The Greek innovation portfolio is predominantly tool-centric, centred on forecasting, behavioural modelling, tariff calculation, monitoring, and optimisation algorithms for DSOs and CPOs. These contributions position the Greek demonstrator as the analytical and operational intelligence backbone of the project. The Greek innovations provide deep functionality in real-time grid awareness and decision support.

Taken together, the Greek demonstrator delivers a robust foundation for smart charging and V2X-enabled grid management. By strengthening advanced analytics, real-time monitoring, and algorithm-driven operational tools, Greece contributes depth in system intelligence and operational readiness, supporting scalable replication of these solutions across increasingly electrified European mobility systems.

4.1.1.3 Portuguese Demonstrator

The Portuguese demonstrator represents a pioneering effort within EV4EU in the field of V2X-enabled demand response (DR), positioning electric vehicles as active distributed energy resources capable of providing flexibility to the grid. Unlike demonstrators that primarily focus on charging control or local optimisation, the Portuguese setup concentrates on market-driven and system-driven mechanisms that allow DSOs to procure flexibility from EVs through structured demand-response frameworks.

At the core of the demonstrator is the development of technical, regulatory, and market mechanisms that enable end users, fleet operators, and aggregators to participate in flexibility markets while respecting distribution network constraints. The ecosystem of participants - including INESC-ID, SEL, the regional authority DRE, utilities such as EDP New, and the DSO EDA - creates a strong interaction between research, regulation, real grid operation, and commercial energy services. This close cooperation allows innovations to be validated under realistic regulatory and operational conditions rather than in isolated technical settings.

The demand-response solutions developed in Portugal explicitly address several systemic challenges identified during the project, including the high cost and long lead times of grid reinforcements, uncertainty related to EV availability and charging behaviour, and the complexity introduced by evolving regulatory frameworks. A further focus is placed on the need for automated and standardised interfaces between DSOs, aggregators, and end users, ensuring scalability and interoperability of flexibility services. By tackling these challenges, the Portuguese demonstrator provides a replicable blueprint for scalable V2X-based demand-response schemes that support higher renewable integration, mitigate peak load stress, and improve long-term system sustainability.

From an innovation portfolio perspective, Portugal contributes 20 innovations in total. Its portfolio displays a balanced structure, with Business Models and Services (9 innovations) and Technologies (7 innovations) forming the dominant groups, complemented by Tools (4 innovations) that support modelling, simulation, and decision-making. This balance reflects Portugal's strategic orientation toward connecting technological development with market implementation. Key innovation themes include green charging, demand response, participation of V2X assets in energy and flexibility markets, and user- and fleet-oriented services. Co-simulation platforms, analytical and planning tools, and advanced fleet-management insights further reinforce this integrated approach.

The Portugal Innovation Portfolio, comprising all identified innovations together with their key information (such as the innovation title, short description, maturity level, involved stakeholders, and relevant technical and business aspects), is compiled and presented in the Appendix 9.4 - Innovation portfolio – Portugal. The appendix serves as a consolidated reference, providing a structured overview of the Portugal innovations and supporting further analysis within the broader project context.

Portugal contributes a strategically balanced innovation portfolio, reflecting a demonstrator design that bridges technology development and market implementation. The Portuguese innovations are centred on V2X-enabled demand response, green charging, fleet services, and participation of EVs in flexibility and energy markets, with a balanced presence of technologies and business models supported by analytical and simulation tools. By combining demand-response mechanisms, grid-service-oriented business models, and enabling technologies within a coherent framework, Portugal makes a critical contribution to the EV4EU innovation pathway, particularly in the areas of regulatory readiness, service design, and scalable market adoption of V2X solutions.

4.1.1.4 Slovenian Demonstrator

The Slovenian demonstrator is one of the most technically advanced components of the EV4EU project, showcasing a comprehensive ecosystem for V2X flexibility management, market participation, and grid service activation. The demonstrator integrates office-based V2X charging infrastructure, household V2X chargers, and a stationary battery energy storage system (BESS), which is used as an innovative emulation platform for electric vehicle fleets. This BESS-based emulation plays a crucial role in the Slovenian setup, as it compensates for the limited availability of bidirectional CCS-compatible EVs and enables realistic, repeatable testing of flexibility services under real operational constraints before availability of the V2X charging stations.

The core objective of the Slovenian demonstrator is to show how a Virtual Power Plant (VPP), operated by GEN-I and closely integrated with Elektro Celje's ADMS, can aggregate V2X capabilities and enable participation across multiple system layers. The demonstrator validates several advanced use cases, including V2X management by a VPP with aggregation of RES and ESS, participation of aggregated V2X assets in electricity and ancillary services markets, activation of grid services and local flexibility markets upon DSO requests, and both manual and automated service activation triggered through ADMS interfaces.

A key innovation of the Slovenian demonstrator is the tight integration between FlexIS, the Slovenian flexibility integration system, and the ADMS. This integration supports end-to-end flexibility processes, ranging from tendering and bidding to activation signals, monitoring, and KPI-based performance analytics, while ensuring compliance with national TSO and DSO requirements. The demonstrator further illustrates how real-time transformer monitoring, forecasting modules, and secure communication layers enable reliable and automated service activation in a fully interoperable operational environment.

In addition, the Slovenian demonstrator significantly advances the validation of bidirectional charging technologies by addressing challenges, including certification requirements, and by identifying practical constraints related to EV availability, charging station software maturity, and OEM collaboration. As such, the demonstrator delivers not only technological advancements but also critical operational insights essential for large-scale V2X deployment in regulated electricity systems.

The Slovenian demonstrator clearly stands out within EV4EU with the largest innovation portfolio, comprising 48 unique innovation entries. This concentration reflects the strong involvement of key national partners - GEN-I, Elektro Celje, ABB, and the University of Ljubljana - as well as the breadth and complexity of the Slovenian demonstrator setup. The innovation portfolio spans flexibility markets, V2X control integration, operational and decision-support systems, and KPI-based evaluation frameworks, positioning Slovenia at the centre of several system-level advancements within the project.

The Slovenian Innovation Portfolio, comprising all identified innovations together with their key information (such as the innovation title, short description, maturity level, involved stakeholders, and relevant technical and business aspects), is compiled and presented in the Appendix 9.4 - Innovation portfolio – Slovenia. The appendix serves as a consolidated reference, providing a structured overview of the Slovenian innovations and supporting further analysis within the broader project context.

From a structural perspective, Slovenia's innovation portfolio is strongly dominated by tools, with 27 tool-type innovations, highlighting its leadership in delivering actionable, operational, and analytics-driven solutions validated in real-world conditions. Business Models and Services, with 13 innovations, form the second largest group, underlining Slovenia's central role in flexibility market design, V2X participation schemes, and aggregator-centric services. These are complemented by 8 technology-focused innovations, which support grid integration, V2X charging infrastructure, and BESS-based solutions.

Slovenia contributes the largest and most diverse innovation portfolio within EV4EU, reflecting the scope and ambition of its demonstrator design. The Slovenian innovation portfolio is strongly system-driven, centred on VPP-based V2X management, integration with ADMS/DMS platforms, flexibility markets, and KPI-based performance evaluation. These contributions position the Slovenian demonstrator as the system-integration and market-activation backbone of the project. While this results in a higher overall number of innovations compared to other demos, many of them are close to commercial readiness and validated under near-real operational conditions.

Overall, Slovenia serves as the system integration and exploitation hub of the EV4EU project, where technologies, digital tools, and business models converge into coherent, market-ready ecosystems validated through advanced demonstrator activities.

4.1.2 Cross Category of Innovation Interpretation

The innovation inventory shows that the 113 innovations developed within the EV4EU project are distributed across three main categories: Tools, Technologies, and Business Models and Services, as presented on the Figure 7 and Table 9. These categories provide a structured way to interpret the nature of innovation outputs across different national demonstration environments.

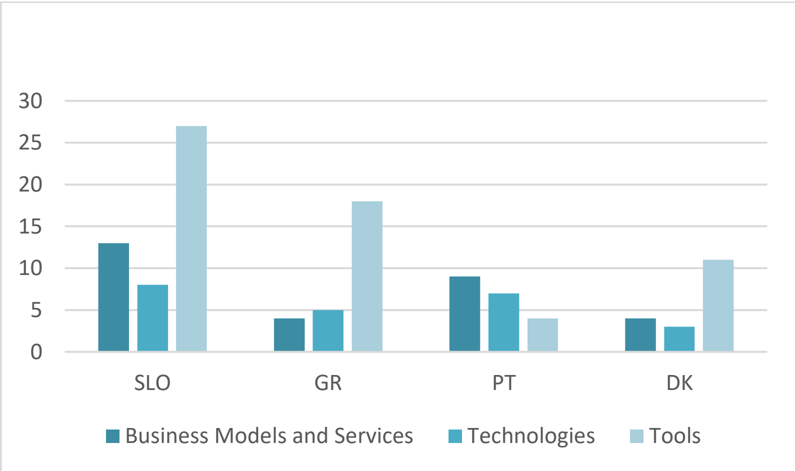


Figure 7: Innovations by Category

The category Tools includes software-based and analytical artifacts such as algorithms, digital platforms, decision support systems, monitoring solutions, forecasting tools, and real-time operational control mechanisms. These innovations primarily support system operation, optimization, coordination, and decision-making processes within V2X, grid, and flexibility contexts. Technologies refer to hardware-centric and infrastructure-related developments, including charging stations, embedded systems, communication modules, firmware, energy management systems, and other technical building blocks required for physical deployment and integration. The category Business Models and Services encompasses innovations related to service design, market mechanisms, contractual arrangements, flexibility offerings, and user- or market-oriented solutions that enable the commercialization and practical adoption of technological and digital results.

The EV4EU project classifies all innovations into three overarching types: Technologies, Tools, and Business Models and Services. While these categories may appear straightforward at first glance, a deeper examination of the innovation dataset shows that each type corresponds to a different functional layer within the V2X ecosystem, reflecting varying levels of maturity, operational purpose, and system integration. These types are not used merely as descriptive labels; rather, they capture the specific roles that innovations play in enabling, operating, and monetising V2X-based flexibility solutions.

Table 9: Number of Innovations by Category

Country	Business Models and Services		Technologies		Tools		Total
SLO	13	27.1 %	8	16.7 %	27	56.2 %	48
GR	4	14.8 %	5	18.5 %	18	66.7 %	27
PT	9	45.00 %	7	35.00 %	4	20.00 %	20
DK	4	22.2 %	3	16.7 %	11	61.1%	18
Total	30	26.5 %	23	20.4 %	60	53.1 %	113

A comparison of category shares by country reveals clear differences in national innovation profiles that reflect the focus and scope of each demonstrator (Figure 8). Slovenia shows a strong dominance of Tools, which account for 56.2% of all Slovenian innovations, complemented by 27.1% Business Models and Services and 16.7% Technologies. This structure indicates a strong emphasis on system-level platforms, operational tools, and market-ready solutions that support end-to-end integration and deployment.

Greece exhibits the highest relative concentration of Tools, representing 66.7% of its innovation portfolio, while Technologies account for 18.5% and Business Models and Services for 14.8%. This distribution reflects a clear focus on algorithms, operational intelligence, monitoring, forecasting, and real-time control capabilities for grid and V2X operation.

Portugal presents the most balanced innovation profile among the participating countries. Business Models and Services and Technologies each represent 40.9% of Portuguese innovations, while Tools account for 18.2%. This balance highlights a combined emphasis on technological development and market- and user-oriented services, indicating strong alignment between technical innovation and practical service deployment.

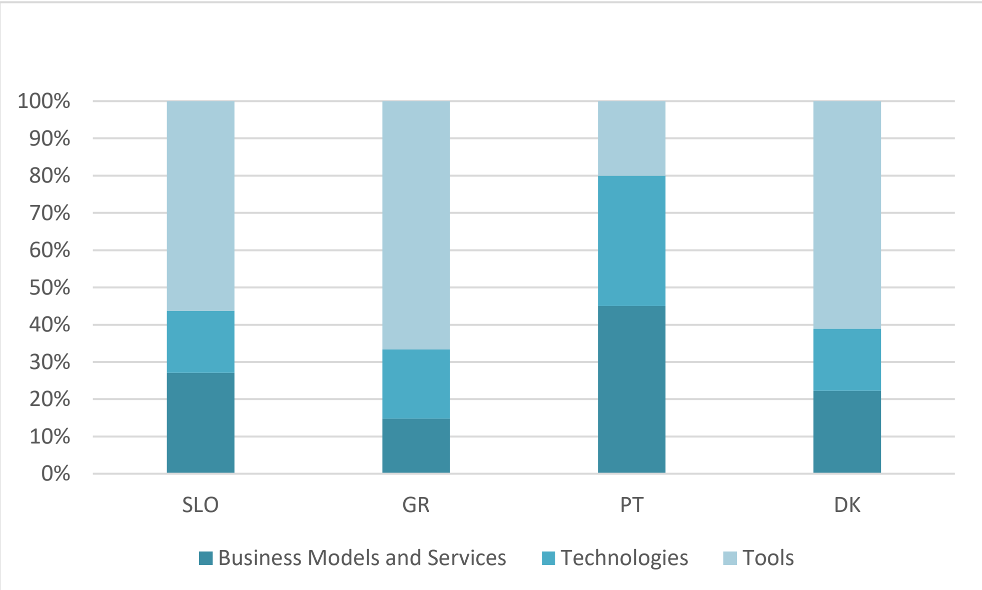


Figure 8: Innovation Category Shares by Country

Denmark, while contributing a smaller absolute number of innovations, shows a profile dominated by Tools at 61.1%, with 22.2% Business Models and Services and 16.7% Technologies. Although Danish innovations include important hardware and infrastructure elements, the overall categorization indicates that these developments are strongly supported by embedded control, management, and operational tooling.

Overall, the distribution of innovation categories across countries provides a clear indication of market readiness pathways within the EV4EU innovation portfolio. Innovations classified as Technologies represent the foundational layer, delivering the hardware, infrastructure, and technical enablers necessary for physical deployment and system integration. These developments form the prerequisite for real-world implementation but typically require further integration, validation, and alignment with operational processes before market uptake. Tools, which constitute the largest share of innovations in several countries, reflect a more advanced stage of readiness, as they translate technological capabilities into operational solutions such as platforms, algorithms, monitoring systems, and decision-support functionalities that can be directly embedded into existing energy and mobility systems. Finally, Business Models and Services are most closely associated with immediate market relevance, as they address commercialization, service delivery, contractual frameworks, and user engagement, enabling innovations to move beyond technical deployment toward sustained economic and societal value creation. Taken together, the category structure observed in the innovation inventory demonstrates that EV4EU has progressed along the full innovation chain - from technological foundations, through operationalization, to market-oriented services - thereby establishing a balanced and coherent portfolio with strong potential for post-project exploitation and real-world adoption.

Overall, the category distribution underscores that differences between countries are driven by the specific objectives and design of national demonstrators rather than by differences in innovation capacity. The cross-country comparison highlights the complementary nature of contributions within EV4EU: system-level tools and operational intelligence, hardware and technological components, and market-oriented services together form a coherent and mature innovation portfolio that supports the large-scale integration of V2X and flexibility solutions across Europe.

4.1.2.1 Technologies – The Physical and Systemic Infrastructure Layer

Technologies represent the tangible and system-level enablers that allow V2X and electric vehicle charging innovations to operate in real-world environments. These innovations typically take the form of hardware components, embedded systems, or infrastructure-grade architectures, and they establish the physical and operational backbone of the project demonstrators.

Representative examples include V2X-capable charging stations developed by ABB, SEL and INESC-ID, and Circle; low-voltage (LV) monitoring systems implemented by HEDNO; charger hardware, PCB designs, and CAD developments by Circle; energy management systems for buildings and parking facilities developed by INESC-ID and DTU; firmware enabling smart charging and V2X operation in EV chargers; CIM-based interoperability infrastructures developed by GEN-I to support system integration.

These innovations are typically associated with high Technology Readiness Levels (near TRL9), as they undergo extensive validation and testing in operational environments within the project demonstrators. Their primary role is to ensure system stability, safety, performance, and interoperability, thereby forming a reliable foundation upon which higher-level digital tools and market solutions can operate.

In interpretative terms, Technologies constitute the “hard” enablers of the EV4EU ecosystem. They are the components that physically interface with the power system: they connect to the grid, measure electrical parameters, communicate with external platforms, and enable the controlled charging and discharging of electric vehicles. Without this technological layer, neither advanced decision-support tools nor innovative business models could be effectively deployed or scaled.

4.1.2.2 Tools – The Intelligence and Control Layer

Tools represent the digital intelligence layer of the EV4EU ecosystem. This category includes algorithms, software platforms, dashboards, forecasting models, optimisation engines, planning systems, decision-support tools, and real-time control frameworks. While technologies provide the physical backbone of the system, tools are what render these technologies intelligent, adaptive, and scalable.

This category is the most prevalent across all demonstrators, with particularly high concentrations in Slovenia and Greece, reflecting a strong emphasis on system operation, real-time decision-making, and analytics-driven coordination of V2X and flexibility services.

Representative examples include forecasting algorithms for transformer loading and day-ahead demand prediction; real-time monitoring, triggering, and alerting frameworks; the V2GFlex simulation and evaluation tool developed by the UL; decision-support tools for Charge Point Operators (CPOs) and Virtual Power Plants (VPPs) developed by GEN-I; co-simulation and planning platforms developed by INESC ID and UL; harmonised KPI evaluation methodologies and tools; and algorithms for load management, routing, prioritisation, and charging optimisation.

Tools transform raw technical capabilities into predictive, optimised, and automated decision-making processes. They are essential for scaling flexibility services, as they enable aggregators, DSOs, and service platforms to coordinate large numbers of charging, discharging, and activation events in near real time while respecting grid constraints, user requirements, and market signals.

From an interpretative perspective, Tools represent the “brain” of the EV4EU ecosystem. They process data, generate forecasts, optimise control actions, and orchestrate interactions between electric vehicles, users, charging infrastructure, and power systems. Without this layer, technological components would remain isolated assets; tools are what transform them into a coordinated, responsive, and economically viable V2X system.

4.1.2.3 Business Models and Services – The Market and Behavioural Layer

The third category comprises innovations that shape market value creation, user behaviour, regulatory alignment, and long-term economic viability. Unlike Technologies or Tools, these innovations are neither physical assets nor standalone software components. Instead, they define how V2X solutions are adopted by users, monetised by market actors, integrated into regulatory frameworks, and scaled beyond the demonstrator phase.

Representative examples include flexible capacity contracts for V2X participation; demand-response programmes implemented across Slovenia, Greece, Denmark, and Portugal; green charging business models; multi-EV smart charging and sharing schemes; EV owner- and aggregator-centric business models developed by GEN-I; fleet management services developed by INESC-ID and GEN-I; market participation and aggregation schemes; and local flexibility market platforms such as FLEXIS.

This category is most prominent in demonstrators that interact closely with end users, aggregators, utilities, DSOs, TSOs, regulators, and market platforms. Reported TRL values in this category typically range from TRL 6 to 8, reflecting the fact that business models and services can only be fully validated once sufficient technical maturity is reached and real-world user behaviour, regulatory constraints, and market dynamics are observed.

In interpretative terms, Business Models and Services represent the "economic logic" and market realisation mechanisms of the EV4EU ecosystem. They translate technological capabilities and digital intelligence into viable services, revenue streams, and regulatory-compliant market solutions. By defining incentives, contractual frameworks, and participation rules, this category is essential for ensuring that V2X solutions are not only technically feasible but also commercially attractive, socially acceptable, and scalable in real energy and mobility markets.

Taken together, the three innovation categories demonstrate that EV4EU has progressed along the full innovation chain. Technologies provide the physical and infrastructural foundation required for deployment, Tools operationalise these technologies through intelligent control and optimisation, and Business Models and Services enable market uptake and long-term value creation. The balanced presence of all three layers across the innovation portfolio confirms that the project outcomes extend beyond isolated technical developments and collectively form a cohesive, market-oriented ecosystem with strong potential for exploitation, replication, and scaling beyond the project lifetime.

4.1.3 Cross Types of innovation Interpretation

The analysis of identified innovations according to their classification shows a clearly structured and balanced innovation portfolio. The distribution of innovation types reflects a deliberate strategy to combine short-term applicability with long-term transformational potential. The majority of innovations fall into the categories of breakthrough innovation, while disruptive and basic innovations represent smaller yet strategically important shares. Table 10 and Figure 9 present the distribution of innovations by type across participating countries.

Table 10: Types of innovations by country

Country	Sustaining	Breakthrough	Disruptive	Basic	Total
SLO	5	29	14	0	**48**
GR	4	21	0	2	**27**
PT	0	14	6	0	**20**
DK	0	18	0	0	**18**
	9	84	20	2	**113**

Breakthrough innovations represent the largest or dominant group within the innovation portfolio. Their high presence indicates that the project does not limit itself to incremental improvements, but actively pursues step-change solutions where clearly defined problems require novel technical or systemic approaches. These innovations often combine advanced algorithms, new control strategies, or innovative uses of existing technologies. Their strong representation highlights the project's ambition to generate solutions that significantly advance the state of the art while remaining oriented toward concrete implementation and validation.

Disruptive innovations are fewer than breakthrough innovations in number but carry a disproportional strategic importance. Their limited share is consistent with their nature, as disruptive innovation typically involves higher uncertainty, stronger dependency on regulatory and institutional conditions, and longer paths to market uptake. The disruptive innovations identified primarily challenge existing operational roles, market structures, or system interactions, particularly in the context of grid operation, flexibility services, and coordination mechanisms. Their selective presence indicates a focused and realistic approach to disruption, targeting areas with high systemic impact rather than widespread structural change.

Sustaining innovations confirms a strong focus on improving, optimising, and adapting existing tools, methods, and system functionalities. These innovations are typically mature, closely linked to real operational needs, and directly applicable within current technical and market frameworks. Their numerical prominence ensures robustness, reliability, and practical relevance of project results, supporting deployment and replication in real-world environments.

Basic innovations form the smallest group within the portfolio. These innovations are exploratory in nature and are mainly related to early-stage concepts, learning models, or foundational research activities. Although their immediate exploitation potential is limited, their inclusion is essential for sustaining long-term innovation capacity. Basic innovations provide the knowledge base from which future breakthrough and disruptive innovations can emerge, ensuring continuity beyond short-term project objectives.

Overall, the numerical distribution across innovation types demonstrates a coherent and well-balanced innovation strategy. The dominance of sustaining and breakthrough innovations supports near- and mid-term impact and deployment readiness, while the presence of disruptive and basic innovations ensures long-term system evolution and knowledge creation. This structure reduces innovation risk, strengthens resilience, and aligns innovation efforts with both practical outcomes and strategic transformation goals.

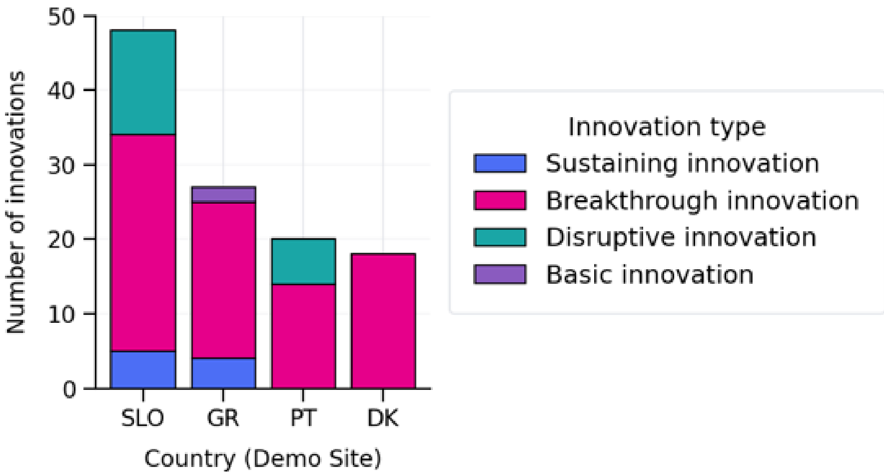


Figure 9: Types of innovations by country

Figure 9 shows the distribution of innovations by country and innovation type based on the demonstrator sites. Slovenia (SLO) records the highest total number of innovations, with breakthrough innovations clearly dominating, complemented by a significant share of disruptive innovations and a smaller number of sustaining innovations. Greece (GR) also shows a strong prevalence of breakthrough innovations, alongside some sustaining innovations, and a very limited presence of basic innovations, indicating ongoing exploratory work. In Portugal (PT), the innovation portfolio is composed primarily of breakthrough and disruptive innovations. Denmark (DK) stands out by featuring exclusively breakthrough innovations, reflecting a strong focus on advanced, solution-oriented developments. Overall, the figure confirms that breakthrough innovations form the core of EV4EU activities across all countries, while other innovation types play a supporting role in system development and evolution.

The analysis of innovations by sub-category reveals a clear concentration of project outcomes in four dominant areas, reflecting strategic priorities related to grid integration, operational digitalisation, decision support, and electric vehicle technologies. These sub-categories not only represent the highest number of innovations, but also capture the areas with the strongest potential for system-level impact and market uptake.

The most prominent sub-category is "Business Models and Services – Grid services", with a total of 14 innovations. This group includes solutions related to flexibility markets, demand response, and green charging. Its size indicates a strong emphasis on enabling electric vehicles and V2X assets to actively participate in electricity markets and grid operation. The high number of innovations in this sub-category reflects the project's ambition to go beyond technical demonstrations and address market design, incentives, and new roles for aggregators, DSOs, and end users. These innovations are particularly important for long-term system transformation, as they directly affect regulatory frameworks and business viability.

The second largest sub-category is "Tools – Operation focused", comprising 12 innovations. These solutions primarily target real-time system operation, including DMS and DSS integrations, monitoring tools, and interoperability mechanisms. The strong presence of operation-focused tools indicates that the project places significant importance on embedding innovations into live operational environments. These solutions are essential for bridging the gap between advanced research outputs and practical deployment, ensuring that new functionalities can be integrated into existing utility and operator systems.

Closely following is "Tools – Decision focused", with 10 innovations. This sub-category includes planning, siting, forecasting, and decision-support tools that aid stakeholders in medium- and long-term decision-making. The number of decisions-focused tools highlights the recognition that effective electrification and V2X integration require not only real-time control, but also robust analytical support for infrastructure planning, investment decisions, and policy evaluation. These tools contribute directly to risk reduction and informed strategic planning for grid operators, service providers, and public authorities.

Finally, "Technologies – EV focused" account for 8 innovations, including V2X charging stations, communication modules, and smart charging hardware. Although smaller in number compared to tools and services, this sub-category represents the technological backbone of many higher-level innovations. These hardware- and firmware-oriented developments are critical enablers, providing the physical interface between electric vehicles and the energy system. Their comparatively lower count is consistent with the higher development effort and investment typically required for hardware-based innovation.

Overall, the distribution of top sub-categories demonstrates a well-balanced innovation portfolio. While EV-focused technologies provide the necessary infrastructure foundation, the dominant presence of tools and grid-oriented services shows a strong orientation toward system integration, operational usability, and market readiness. This balance confirms that the project addresses innovation across the full value chain, from physical assets to digital platforms and market mechanisms, thereby maximising both immediate applicability and long-term impact.

4.1.4 Cross Maturity Interpretation

Technology Readiness Level (TRL) values are provided for all innovations, enabling a robust assessment of the overall technological maturity achieved within the project. A significant indicator of progress achieved during the project is the maturity level of the developed innovations. The majority of innovations reached medium to high levels of technological and innovation readiness, with most results positioned around TRL and IRL levels 6 to 8. This demonstrates a clear transition from conceptual development towards implementation, validation, and demonstration in realistic operational environments. Such maturity levels confirm that the innovation activities did not remain at an exploratory stage but resulted in solutions that were tested and assessed within real demonstrators. The maturity distribution is concentrated in the mid-to-high bands for both TRL and IRL, indicating that most innovations have progressed beyond early validation and are close to demonstration and exploitation Table 11.

Table 11: Innovation maturity distribution by TRL/IRL bands (N=113)

Level bands	Low (1–3)	Mid (4–6)	High (7–9)	Total
TRL	1	44	68	**113**
IRL	1	37	75	**113**

When grouped into broad maturity bands, the TRL distribution shows 63 innovations in the high band (7–8), 44 in the medium band (4–6), 5 in the very high band (9), and 1 in the low band (1–3). The IRL distribution is even more concentrated in the high band, with 74 innovations at IRL 7–8, 38 at IRL 4–6, and 1 at IRL 9. In addition, the project also identified several promising innovations that are outside the direct scope of project implementation. These innovations currently exhibit lower TRL and IRL levels but were nonetheless included in the project's Innovation Register, as they represent important research and development opportunities to be further developed beyond the project duration.

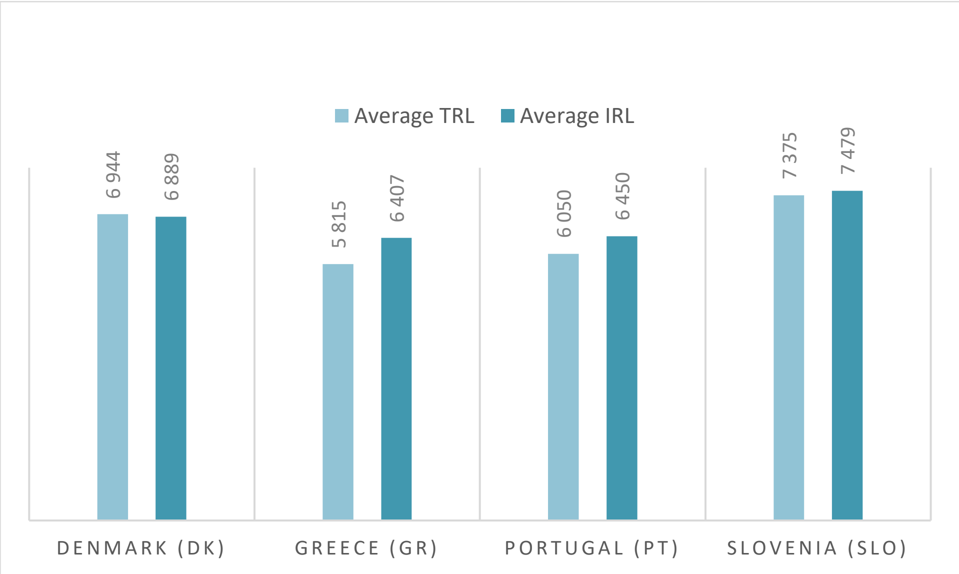


Figure 10: Average TRL and IRL by Country

Across the full portfolio, the average Technology Readiness Level (TRL) for the consortium is 6.70 (Table 12). This indicates that, on average, innovations have progressed beyond laboratory validation and are positioned at the stage of technology demonstration and validation in relevant or operational environments. The concentration of TRL values around level 7 confirms that the project predominantly focused on advancing technologies toward deployment-ready solutions rather than remaining at early conceptual or exploratory stages.

The consortium-level TRL result reflects the strong emphasis on demonstrator-driven innovation within EV4EU. Many technologies were developed, integrated, and tested within real or near-real operational contexts, including charging infrastructure, grid interaction mechanisms, digital platforms, and flexibility management solutions. The relatively high average TRL further suggests that a significant share of the project outcomes can be considered suitable for follow-up activities such as large-scale pilots, replication in other regions, or early market uptake.

Overall, the TRL assessment demonstrates that EV4EU has successfully delivered a technologically mature innovation portfolio, providing a solid foundation for post-project exploitation, standardisation efforts, and further industrial or market-oriented development.

Table 12: Average TRL and IRL by Country

Country (Demo Site)	*Average TRL*	*Median TRL*	*Average IRL*	*Median IRL*	*N*
Denmark (DK)	*6.944*	*7.00*	*6.889*	*7.00*	*18*
Greece (GR)	*5.815*	*6.00*	*6.407*	*6.00*	*27*
Portugal (PT)	*6.050*	*6.00*	*6.450*	*6.00*	*20*
Slovenia (SLO)	*7.375*	*7.00*	*7.479*	*7.00*	*48*
Total	***6.70***	***7.00***	***6.95***	***7.00***	***113***

Slovenia's innovation portfolio is closest to deployment readiness, with a median maturity at TRL/IRL 7.00. Denmark and Greece are converging toward the same maturity band, particularly in technology and tool driven innovations. Portugal exhibits the widest maturity pipeline, ranging from early conceptual work to piloted solutions, which is particularly valuable for upstream innovation, regulatory learning, and long-term market development narratives within the project.

The combined view of average TRL and IRL by country provides insight not only into the maturity of individual innovations, but also into how effectively these innovations have been integrated into real-world operational environments within each national demonstrator. Slovenia exhibits the highest overall maturity, with both TRL and IRL values clustered around level 7.4, indicating a portfolio that is close to deployment readiness and characterised by strong alignment between technological development and system integration. This reflects the presence of large-scale, system level demonstrators in Slovenia, where solutions are tested end to end across technical, operational, and market layers.

Denmark and Greece follow with comparable mid to high maturity profiles. Denmark shows consistently high TRL and IRL values, slightly below Slovenia, which is in line with its focus on technologically mature hardware, control algorithms, and charging infrastructure validated in operational settings. Greece demonstrates a balanced TRL and IRL profile as well, confirming that its innovations - primarily centred on grid intelligence, monitoring, and operational tools - are not only technically advanced but also well integrated into DSO and platform environments.

Portugal presents a different maturity pattern, with a lower average TRL but a relatively higher IRL. This indicates a broader innovation pipeline that includes early-stage concepts alongside more mature, integrated solutions. The observed gap reflects Portugal's emphasis on modelling, planning tools, regulatory exploration, and user centric innovation, where integration into demonstrators often precedes full technological maturity. Such a profile is characteristic of upstream innovation activities that support long-term system design, regulatory learning, and scalability. Within the project, the Portuguese partners devoted efforts to expanding the research scope and identified additional innovations that were not part of the originally planned project research activities. These additional innovations were included in the project's Innovation Register. Their current Technology Readiness Levels (TRLs) are lower, and further development will continue after the completion of the project through subsequent research and development activities.

Across the EV4EU innovation portfolio, IRL values are consistently high, indicating that the project placed strong emphasis not only on technological development but also on system integration, interoperability, and operational deployment. In many cases, innovations were tested within demonstrators involving multiple actors, such as DSOs, aggregators, EV users, charging infrastructure operators, and market platforms, which directly contributed to their integration maturity.

The IRL assesses the extent to which an innovation is integrated into a broader technical, operational, market, and regulatory context. While TRL focuses primarily on technological maturity, IRL captures the readiness of an innovation to operate as part of a system, including interactions with other components, platforms, stakeholders, and real-world processes.

Slovenia records the highest average IRL (7.48 across 48 innovations), reflecting deep integration of solutions into real operational environments, including local flexibility markets, VPP platforms, DMS systems, and coordinated V2X services. The high IRL demonstrates that Slovenian innovations are not standalone components but are embedded within functioning system architectures and institutional settings.

Denmark follows with an average IRL of 6.89, showing a similarly strong level of integration, particularly in relation to charging infrastructure, energy management systems, and interactions with local grid constraints. This indicates that Danish innovations have progressed beyond isolated pilots toward coordinated system-level operation.

Greece and Portugal achieve average IRL values of 6.41 and 6.45, respectively. Although some technologies in these countries remain at slightly lower TRL stages, their IRL results confirm that many innovations are already well integrated into operational environments, market mechanisms, and coordination frameworks. This pattern suggests that integration activities, such as interoperability testing, demand-response participation, and service coordination, are advancing in parallel with technological development.

At the consortium level, the average IRL of 6.95 (across all 113 innovations) confirms that EV4EU has successfully moved beyond isolated technology development toward system-ready and deployment-oriented solutions. Overall, the IRL assessment demonstrates that EV4EU innovations are largely prepared to operate within complex energy and mobility ecosystems, providing a strong foundation for replication, scaling, and post-project exploitation in real market and regulatory settings.

Overall, the TRL/IRL comparison confirms that differences in maturity across countries are structural and demonstrator driven. Together, the national portfolios cover the full maturity spectrum - from development and validation to near deployment - ensuring that the EV4EU project delivers both immediately exploitable results and a sustained pipeline of innovations for future large-scale V2X deployment in Europe.

Overall, the TRL and IRL assessment demonstrates that the EV4EU portfolio represents a mature and well-integrated set of innovations, providing a robust foundation for further scaling, replication, and post-project exploitation in real energy and mobility markets.

4.1.5 WP-mapping of the innovations

The mapping of innovations across work packages shows that the majority of innovation activities are concentrated around the WPs dedicated to demonstrators, confirming their central role in generating, validating, and integrating project results. In particular, WP7, WP8, WP6, and WP9, which are directly linked to national demonstrators, account for most innovations across tools, technologies, and business models. At the same time, it is important to note that the fundamental concepts, methodologies, and core building blocks underpinning these innovations were developed in earlier work packages, which provided the scientific, technical, and methodological foundations for the subsequent demonstrator-driven innovation development.

WP7 stands out as the main innovation hub, hosting a broad spectrum of developments ranging from grid services and flexibility markets to decision-support tools and EV-focused technologies. WP8 and WP9 strongly complement this role by focusing on operational, monitoring, control, and infrastructure-related innovations that are essential for demonstrator execution. WP6 contributes significantly through user-centric solutions and business models that support demonstrator use cases and market uptake.

At the same time, other WPs (such as WP1, WP2, and WP4) also influenced the innovation landscape by providing foundational research, methodologies, regulatory insights, and analytical frameworks. Although these WPs host fewer directly exploitable innovations, they play a critical enabling role by shaping concepts that later materialise and are validated within demonstrator-focused WPs.

Overall, the WP mapping confirms that innovation activities are primarily anchored in demonstrator-oriented WPs, while upstream and transversal WPs provide essential inputs that strengthen coherence, maturity, and long-term impact of demonstrated solutions.

4.1.6 Cross-Demo Common Innovations and KERs

The analysis of innovations across EV4EU shows a consistent set of common innovations that appear repeatedly in multiple national pilots. These recurring innovations are not the result of simple duplication, but rather reflect the use of different technical solutions, system architectures, and demonstrator designs that address similar functional objectives under varying regulatory, operational, and market conditions.

The most widely replicated innovation is Green charging, which appears in four demonstrators, confirming its role as a core system-level concept linking renewable integration, grid-aware charging, and user incentives. Other highly recurrent innovations include V2X Station, Decision Support Tools for VPPs and CPOs, Demand Response for V2X, and Sharing charging, each appearing in three demonstrators. These innovations represent key building blocks of V2X ecosystems, enabling flexibility activation, user coordination, and interaction between EVs and power systems.

A second group of common innovations appears in two demonstrators, including Co-simulation platforms for V2X, EV Fleet Management Services, Open V2X management platforms, Flexible capacity contracts for V2X, Participation of V2X in markets and services, Houses/Building/Parking Lot energy management systems, Integration of V2X management in DMS, Additional functionalities of ADMS, and Flexible services for local markets. While these innovations share common functional goals, their concrete implementations differ significantly across countries, reflecting local grid structures, institutional roles, and demonstrator objectives.

The recurrence of these innovations across multiple demos is therefore primarily driven by the diversity of approaches used to implement similar concepts, rather than by uniform replication of identical solutions. Different partners adopt distinct architectures, interface designs, control strategies, and business arrangements to address the same underlying challenges, such as flexibility provision, grid integration, and user engagement. This diversity strengthens the overall innovation portfolio by validating core concepts under heterogeneous conditions. The repetition of innovations occurs as a direct consequence of partners integrating demonstrators into different infrastructures, as well as due to the fact that several partners built upon pre-existing solutions that were subsequently upgraded with V2X functionalities.

Taken together, these recurring innovations form a coherent set of cross-demo common innovations with high replication and scale-out potential. Their validation across multiple demonstrators significantly reduces technical and systemic risk and makes them strong candidates for dedicated treatment in deliverables, exploitation plans, and future deployment roadmaps.

4.1.6.1 Relationship between Innovations and Key Exploitable Results (KERs) in the EV4EU Project

In the EV4EU project, a clear and systematic distinction is made between innovations and Key Exploitable Results (KERs), while at the same time maintaining a strong and traceable link between them (Figure 12). This distinction is essential for structuring the innovation process in a transparent and manageable way, supporting exploitation planning, and ensuring clarity regarding partner contributions and Intellectual Property Rights (IPR).

Within EV4EU, innovations represent the full spectrum of novel or significantly improved outcomes generated during the project. These results span technical solutions and system architectures, algorithms and control strategies, methodological approaches, digital platforms and tools, as well as business models and operational concepts. Innovations capture the creative, research-driven, and development-oriented output of the project and reflect its overall innovative capacity.

Innovations may vary considerably in scope, maturity, and readiness. In many cases, they consist of multiple interrelated components that are developed across different work packages and validated through different demonstrators. As such, innovations act as the foundational building blocks of EV4EU's achievements, documenting progress across technical, organisational, and market-oriented dimensions.

However, not all innovations are automatically suitable or ready for direct exploitation. Some outputs remain exploratory, some primarily support demonstrator validation without immediate standalone market value, and others only become exploitable when combined with additional components or after further development beyond the project lifetime.

The identified innovations emerging from demonstrators and pilot implementations are clustered based on shared functionalities, infrastructure contexts, and V2X enhancements. These clusters form the basis for defining and consolidating the KERs, which represent mature, reusable, and exploitation-oriented outcomes of the project.

Key Exploitable Results are derived from the broader innovation landscape of EV4EU and represent a carefully selected subset of innovations with clear and identifiable exploitation potential. A KER is defined as a project result that can be further used in research and innovation activities, transferred to external stakeholders, replicated in other technical or geographical contexts, or exploited commercially or operationally by one or more partners.

Unlike general innovations, each KER represents a clearly delimited and sufficiently mature result. For every KER, it is possible to explicitly define ownership and access rights, partner contributions, intended exploitation pathways - such as internal use, commercial deployment, or further development - and the associated IPR arrangements. In this way, KERs form the main interface between innovation and exploitation within EV4EU, translating broader innovation outputs into concrete, manageable, and exploitable entities.

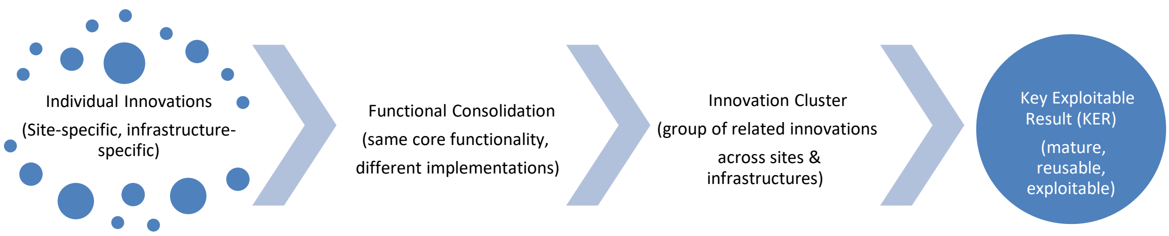


Figure 11: Connection between innovations and KERs

The relationship between innovations and KERs is hierarchical, but it is not strictly one-to-one. Several configurations occur within the project. In some cases, a single innovation leads to multiple KERs, for example when a technical platform gives rise to both a technological exploitation opportunity and a separate business or service-oriented result. In other cases, a single KER is built upon multiple innovations, such as when algorithms, system integration concepts, and operational frameworks together form one coherent exploitable solution.

For this reason, EV4EU treats innovations as the input layer of the innovation process, capturing the full breadth of project results, while KERs constitute the structured output layer focused on exploitation, impact, and long-term sustainability.

KERs play a central role in IPR management and in ensuring transparency among project partners. While innovations may involve multiple contributors and evolve iteratively over time, each KER serves as a stable reference point for clearly documenting which partners led and contributed to its development, defining who holds the resulting rights, and clarifying how the result can be used both within and beyond the consortium.

Within EV4EU, all innovations were systematically reviewed in order to identify those with exploitation potential. Where such potential was identified, KERs were defined and formalised. For each KER, partner contributions, ownership structures, and access rights were explicitly agreed, ensuring legal clarity, traceability, and alignment with consortium and grant agreement requirements.

Based on the analysis of the innovation portfolio, the linking between innovations and Key Exploitable Results (KERs) follows a non-linear, many-to-many patterns. Out of a total of 113 identified innovations, 39 innovations (around one third) are directly linked to at least one KER, while the remaining innovations represent technical, methodological, or contextual building blocks that support KER development indirectly. In total, 28 distinct KERs are identified. Most linked innovations are associated with a single KER, while a smaller subset contributes to multiple KERs, reflecting their cross-cutting relevance across use cases or value chains. At the same time, more than half of the KERs are supported by multiple innovations, demonstrating that KERs are typically derived through the consolidation of several related innovations implemented across different infrastructures and demonstration sites. This statistical distribution confirms that innovations act as foundational elements, while KERs represent consolidated, mature, and exploitation-ready outcomes rather than direct one-to-one results.

In summary, innovations within EV4EU represent the complete and comprehensive set of novel technical, methodological, and business results generated by the project. KERs, in contrast, represent a carefully selected and structured subset of these innovations that are sufficiently mature, exploitable, and clearly attributable in terms of ownership and partner contributions. KERs are derived from innovations and serve as the primary instruments for exploitation planning, IPR management, and long-term impact creation. This structured relationship ensures coherence between research, demonstration, and exploitation activities, while safeguarding partner interests and supporting the sustainable use of EV4EU results beyond the project lifetime.

The EV4EU innovation inventory records a large number of individual innovations, which serve as building blocks for a smaller set of KERs. The relationship between innovations and KERs is not one-to-one: multiple innovations typically contribute to the same KER, while individual innovations may support several KERs simultaneously. The resulting shows how multiple innovations are consolidated into a limited number of exploitation-oriented KER clusters, such as Green Charging, Demand Response for V2X, and Flexibility and Market Participation. This visualisation highlights the many-to-many natures of the innovation–exploitation relationship within EV4EU, where KERs emerge from the aggregation of several complementary innovations rather than from one-to-one mappings (Table 13).

Table 13: Relationship between KER clusters and innovations

KER cluster	Number of linked innovations	Description
Green Charging	12	Innovations enabling RES-aware, grid-friendly and incentive-based EV charging strategies
Demand Response for V2X	8	Innovations supporting aggregation and activation of EV flexibility through demand response schemes
Flexibility & Market Participation	10	Cross-cutting innovations enabling participation of EVs and V2X assets in flexibility and energy markets
V2X Station	4	Innovations related to V2X-capable charging infrastructure and station-level functionality
Sharing Charging	3	Innovations focused on shared and load-balancing charging concepts and user coordination

The diagram at Figure 12 shows the explicit links between individual innovations and KERs clusters. We also analysed the relationships for each individual demonstrator and developed a diagram illustrating the links between innovations and KERs, as shown in the example of the Slovenian demonstrator in the figure.

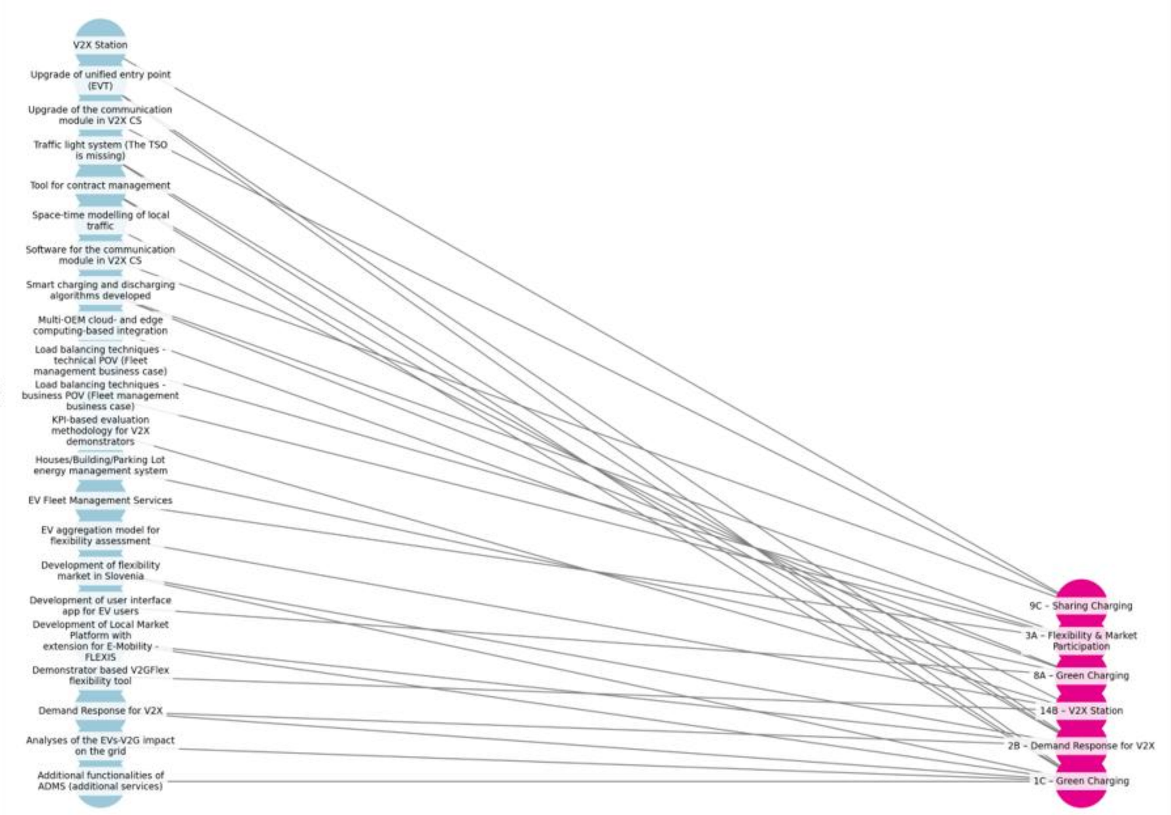


Figure 12: Innovation–KER cluster traceability network

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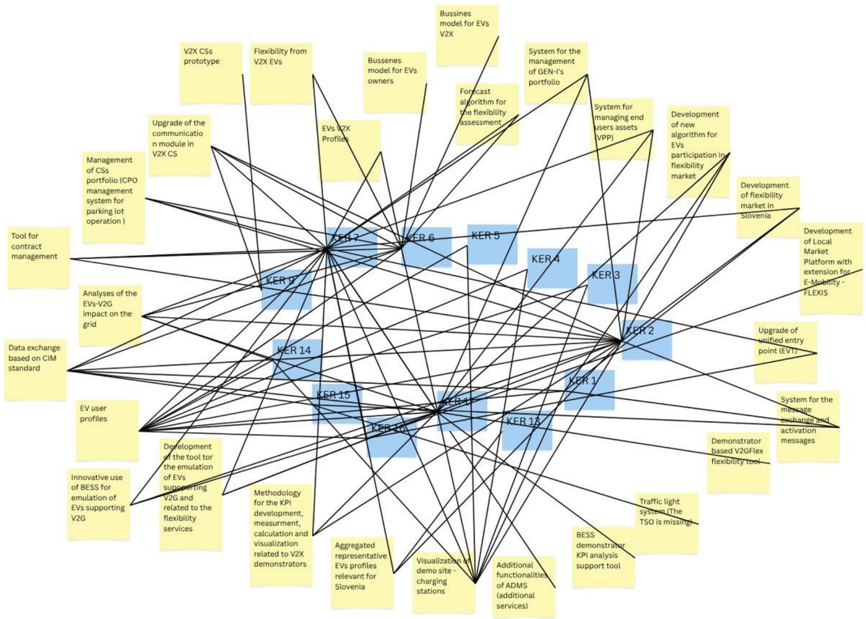

Figure 13: Innovation - KER connections for the Slovenian demo

4.1.6.2 Cross-Demo Common KERs

The repeated appearance of the same innovation themes across different demos is a strong indicator of high replication and scale-out potential, as these solutions have proven relevance under diverse regulatory, technical, and operational conditions.

Among the most prominent cross-demo KERs, Green charging stands out as the only innovation theme implemented in all four demonstrators (Denmark, Greece, Portugal, and Slovenia), albeit with different national leads and implementation emphases. This confirms green charging as a core, system-level solution linking renewable integration, user incentives, and grid-aware charging strategies.

Demand Response for V2X is another highly replicated KER, appearing in Portugal, Slovenia, and Greece (with supporting validation elements also present in Denmark). Its recurrence demonstrates the strategic importance of positioning EVs as flexible, dispatchable resources that can be procured by DSOs through market-based or regulated mechanisms.

A wider group of KERs appears consistently across two or more demonstrators, further confirming their maturity and cross-context applicability. These include Sharing charging, V2X Station, Houses/Building/Parking Lot Energy Management Systems (EMS), Integration of V2X in DMS, Participation of V2X in markets and services, Flexible services for local markets, Flexible capacity contracts for V2X, and EV Fleet Management Services. While the technical implementations and business roles vary between countries, the functional concepts are shared, indicating convergence toward common architectural and market patterns.

Taken together, these recurring KERs represent a natural cluster of "Cross-demo KERs" suitable for focused exploitation, replication, and scale-out activities. They are strong candidates for dedicated treatment in project deliverables and exploitation plans, as well as for inclusion in future roll-out roadmaps targeting broader European deployment. Their validation across multiple demonstrators significantly reduces technical, regulatory, and market risk, positioning them as cornerstone solutions for large-scale V2X adoption.

4.2 Analyses of the Innovation metrics

A list of innovation performance indicators, herein named Innovation Metrics (IM), has been defined and will be utilized during the course of the EV4EU project. These Innovation Metrics are presented in Table 14.

The project significantly exceeded its innovation targets across all monitored Innovation Metrics (IMs). In particular, dissemination and scientific output performed strongly, with 59 scientific publications and conference presentations achieved against a target of 25 (IM1). The development of concrete project outputs was especially notable, with 60 new tools, 30 new Business Models and Services, and 25 new technologies, far surpassing the initially defined targets (IM2, IM7, IM8).

Collaboration and ecosystem engagement also exceeded expectations, with 27 liaisons and joint activities established with external projects and initiatives, compared to a target of 20 (IM3). Dissemination and demonstration activities met or exceeded all goals, including 4 scientific/technical dissemination materials, 4 demonstration reports, 7 demo events, and demonstrations conducted across 6 different locations, beyond the planned four (IM4–IM6, IM9).

Overall, the achieved results demonstrate a strong overperformance of the project in terms of innovation output, dissemination impact, and real-world demonstration, confirming the high relevance and maturity of the developed solutions.

Table 14: Innovation metrics

IM ID	Innovation Metrics description	IM target value	Achieved value
IM1	Number of scientific publications and conference/congress presentations on advanced methods and tools.	25	59
IM2	Number of new tools.	5	60
IM3	Number of liaisons and joint activities with other projects, communities, initiatives	20	27
IM4	Number of scientific/technical dissemination material	3	4
IM5	Number of demonstration reports	4	4
IM6	Number of different locations where the demonstrations will take place	4	6
IM7	Number of new Business Models and Services	4	30
IM8	Number of new technologies	3	25
IM9	Number of demo events	4	7

The achieved values across all Innovation Metrics clearly demonstrate that the project not only met but substantially exceeded its original ambitions. The strong overperformance in scientific output and dissemination confirms the high scientific relevance and credibility of the developed methods, tools, and solutions. At the same time, the exceptionally high number of new tools, technologies, and business models reflects the project's solution-driven and implementation-oriented approach, with a strong emphasis on practical applicability and real-world deployment beyond purely conceptual results.

The expansion of demonstrations to a higher number of locations than initially planned further strengthened the robustness, transferability, and replicability of the project outcomes across different regulatory, technical, and market contexts. Moreover, the high number of joint activities and liaisons illustrates the project's active integration into the wider European innovation ecosystem, fostering alignment with parallel initiatives and contributing to long-term impact beyond the project lifetime.

Overall, the Innovation Metrics confirm that the project delivered a mature, diversified, and exploitation-ready portfolio of results, combining scientific excellence with concrete technological and business innovations, and providing a strong foundation for sustainable uptake and market deployment.

5 Intellectual Property Rights

During the EV4EU project, new developments were continuously analysed to identify those with potential for commercialization and, where appropriate, protection through intellectual property rights (IPR). By the end of the project, a detailed overview of result ownership was established, clarifying the allocation of IPR among partners. In line with the European Commission's Open Science policy, project results were published in Open Access formats to ensure broad accessibility for researchers and the general public. Publications were made openly available through trusted EC repositories, licensed under CC BY or equivalent licences (or CC BY-NC/ND where justified), with supporting research outputs and validation tools clearly referenced. Metadata were released under CC0 licences in accordance with FAIR principles.

Throughout the project, EV4EU actively involved relevant knowledge actors, including citizens, civil society organisations, and end users, through the Stakeholders Board. Prior to dissemination and communication activities, all research results underwent an IPR assessment to determine their protection potential, in compliance with the Grant Agreement, national regulations, and the guidelines of the EC IPR Helpdesk. Where exploitation uptake will not be achieved within one year after project completion, exploitable results will be prepared for visibility through the Horizon Results Platform.

IPR management followed the framework defined in the Grant Agreement and the Consortium Agreement. All partners contributing background knowledge or generating foreground results declared their IPR to the project coordinator, including any special requirements for use. Confidentiality, ownership, access rights, protection measures, and exploitation conditions were clearly established at the start of the project and applied throughout its implementation. Commercial aspects such as joint ownership, patenting, sublicensing, availability of results for other EU projects, and liability rules were addressed and managed in accordance with the agreed framework. In addition, dedicated training sessions on Intellectual Property Rights (IPR) were organised for project partners to support the identification, protection, and exploitation of project results.

Each partner retained ownership of knowledge generated independently within the project. For jointly developed results, ownership was shared among the contributing partners in proportion to their respective efforts. Partners were granted the right to exploit project results in line with the Consortium Agreement, supporting competitiveness and market uptake of EV4EU outcomes. Joint IP could be exploited by contributing partners in accordance with agreed rules, ensuring flexibility while safeguarding consortium objectives.

Patent-related procedures were implemented during the project. Partners intending to submit patent applications informed the Project Management Committee and coordinated with the project coordinator in cases of potential conflict. Patent-related information was reported to the European Commission through regular management reporting, and associated costs were borne by the submitting partners.

Throughout the EV4EU project, IPR were diligently, consistently, and transparently monitored in line with the innovation strategy, the Grant Agreement, and the Consortium Agreement. A structured IPR management and tracking approach was applied across the entire project lifecycle to ensure full clarity regarding contributions, ownership, and exploitation rights.

For all developed innovations and all identified KERs, the roles and contributions of the involved partners were clearly documented. It was explicitly defined who contributed what, who led the development of each result, and which partner(s) hold the corresponding rights. This ensured full transparency and traceability of responsibilities and ownership across all innovation activities.

In parallel, detailed IPR and patentability analyses were carried out for each innovation and each KER. These analyses assessed novelty, inventive step, freedom to operate, market relevance, and strategic value of potential patent protection. Based on these assessments, some need for patent applications was identified. Three patents' applications were initiated during the project, of which one has already been formally filed; additional applications are planned post-project. For other innovation no need of patent was justified by the fact that the majority of project results are based on:

- system integration concepts and architectures,
- software-based algorithms and control strategies,
- business models, operational frameworks, and coordination mechanisms, and
- platform-oriented and interoperability-focused solutions,

where patenting would not significantly increase protection, exploitation potential, or market uptake. In these cases, clear ownership definition, know-how protection, contractual arrangements, and first-mover advantage were identified as more suitable and proportionate mechanisms than formal patent protection.

The analysis of patenting activities and Intellectual Property Rights (IPR) indicates that formal patent protection has been applied selectively, primarily for technologically mature, hardware-based, or standard-driven solutions. In contrast, the majority of project innovations rely on copyright, trade secrets, and proprietary know-how as the main protection mechanisms. This reflects the nature of the project results, which are predominantly digital, software-based, systemic, and business-oriented, where patenting is often not the most suitable or efficient form of IPR protection. Furthermore, the analysis reveals a distributed IPR ownership structure across multiple partners, highlighting the importance of early alignment on ownership, access rights, and exploitation responsibilities. This need was further addressed through dedicated IPR training sessions organised for project partners.

Overall, this approach ensured that IPR ownership is clearly defined, legally sound, and aligned with each partner's contribution, while at the same time enabling effective exploitation, dissemination, and future development of EV4EU innovations beyond the project duration.

To support transparency, planning, and dispute prevention, an IPR Directory was maintained and regularly updated throughout the project lifetime. This directory documented all project-related knowledge items, specifying ownership, nature of the results, exploitation potential, access rights, dissemination intentions, and applied or planned protection measures. The IPR Directory, together with the Consortium Agreement, provided a clear and agreed framework for future exploitation and commercialization of EV4EU results.

Overall, the project adopted a balanced and pragmatic approach to Intellectual Property Rights (IPR), aligned with the diverse nature and maturity of its results. Rather than relying predominantly on patenting, partners applied a portfolio of IPR protection mechanisms, including copyrights, trade secrets, proprietary know-how, and contractual arrangements, complemented by selective patenting where appropriate. This approach enabled both flexibility and protection across technological, digital, and business-oriented innovations. The distributed ownership of IPR among partners reflects the collaborative and multi-actor structure of the project, while continuous coordination and targeted IPR training ensured a shared understanding of ownership, access rights, and exploitation pathways. As a result, the project established a solid IPR framework that effectively supports the sustainable exploitation and long-term impact of its Key Exploitable Results.

6 Future Plans regarding EV4EUs Innovation portfolio

The EV4EU project was conceived and implemented with the vision of developing and enabling innovative, user-centric, and market-ready solutions that transform electric vehicles from passive assets into active participants of the energy system. Throughout the project, these solutions contributed to transport decarbonisation, power system stability, and the efficient integration of renewable energy sources, demonstrating the strategic role of electric vehicles in Europe's energy transition.

The innovations developed within EV4EU addressed the technical, economic, and regulatory dimensions of Vehicle-to-Everything (V2X) technologies, making them more reliable, viable, and feasible for real-world deployment. The project successfully enabled electric vehicles to participate in electricity markets, flexibility services, and grid services at both local and national levels. A central objective of EV4EU was to bridge the gap between research activities, large-scale demonstrations, and market uptake, and this objective was achieved through extensive piloting, validation, and stakeholder engagement.

A strong focus was placed on the development of new business models, advanced control algorithms, and digital platforms, facilitating cooperation along the entire value chain, including EV users, aggregators, DSOs, TSOs, and charging infrastructure providers. Throughout the project, innovation design consistently prioritised user comfort, data protection, trust, and transparency, ensuring that technological progress translated into tangible value for all involved actors.

All innovations produced within EV4EU were designed and demonstrated as scalable, interoperable, and replicable solutions, adaptable to diverse regulatory, market, and geographical contexts across Europe. This approach ensured not only the robustness of demonstrator results, but also the long-term sustainability and exploitability of the project outcomes.

Importantly, the conclusion of the EV4EU project does not represent the end of the innovation process. On the contrary, project partners are committed to continuing the development, refinement, and exploitation of the identified innovations and Key Exploitable Results (KERs) beyond the formal project lifetime. The most mature solutions, validated through multiple demonstrations and integration environments, provide a solid foundation for further industrialisation, commercial deployment, and follow-up research and innovation activities.

Ultimately, EV4EU has laid the groundwork for a connected, flexible, and user-driven energy ecosystem, where electric vehicles are no longer passive energy consumers but active providers of flexibility, resilience, and system innovation. Building on the results achieved during the project, partners intend to further strengthen this ecosystem after project completion, supporting Europe's transition towards a climate-neutral, digitally enabled, and market-oriented energy system.

Following the completion of the EV4EU project, partners plan to continue developing and scaling the most promising innovations and Key Exploitable Results (KERs) identified during the project. The forward-looking plan focuses on five main strategic directions:

1. Scale-out of high-potential cross-demo KER clusters - Post-project activities will prioritise a limited set of cross-demonstrator KER clusters with the highest replication and deployment potential, including Green Charging, Demand Response for V2X, V2X–DMS integration, Sharing / Load-balancing Charging, and Participation of V2X in Markets. These clusters will form the basis for scale-out initiatives supported by country-specific deployment playbooks.
2. Use Slovenia as a reference deployment model - The Slovenian demonstrator will serve as a reference architecture for future commercial and large-scale deployments. The focus will shift from demonstrator KPIs towards commercial performance indicators, enabling smoother

transition from validated pilots to market-ready solutions and reduced integration risks for new adopters.

3. Further clarification and strengthening of IPR for shared assets - To enable post-project exploitation, partners will further clarify IP ownership, licensing models, and exploitation leadership, particularly for jointly developed assets. This will support smoother commercial uptake and long-term collaboration beyond the project lifetime.
4. Improved governance through innovation data harmonisation - The innovation registry will be further refined by standardising metadata, categories, and KER mappings, improving traceability, governance, and reporting efficiency for future projects and investors.
5. Position EV4EU as a strong reference for future funding and industry uptake - Building on the achieved results, EV4EU outcomes will be communicated through a clear and consistent narrative highlighting grid benefits, user value, and market opportunities. This positioning will support follow-up investments, policy alignment, and new research and innovation initiatives after the project's completion.
6. Continued partner-led development and market uptake of results - Beyond joint exploitation activities, each project partner will continue to further develop, mature, and commercialise its own innovations and associated KERs after the formal end of the EV4EU project. Partners plan to build on the results achieved within EV4EU by advancing technology readiness, refining business models, integrating solutions into their existing product and service portfolios, and pursuing direct market uptake. This decentralised yet aligned approach ensures that the project's outcomes remain active, evolving, and market-oriented, while maximising the long-term impact of EV4EU through individual exploitation pathways tailored to each partner's role, capabilities, and strategic objectives.

Based on the defined and agreed IPR framework established during the EV4EU project, the further development of innovations and KERs is expected to continue in a clear, structured, and efficient manner after the project's completion. The early identification of ownership, access rights, and exploitation responsibilities has reduced legal and organisational uncertainties, enabling partners to build confidently on the project results. This clarity supports smooth post-project collaboration, independent partner-led development, and market-oriented exploitation, while respecting consortium agreements and individual partner strategies. As a result, the defined IPR rules serve as a stable foundation for continued innovation, scaling, and commercialisation beyond the project lifetime.

Beyond the formal conclusion of the EV4EU project, the partnership established during the project is expected to remain active and continue its collaboration. The strong technical, industrial, and research links built through joint demonstrations, innovation development, and exploitation activities have created a shared basis for continued cooperation. Partners expressed a clear intention to further collaborate on follow-up projects, joint market initiatives, standardisation activities, and bilateral or multilateral developments, building on the trust, complementarities, and shared vision developed within EV4EU. In this way, the EV4EU consortium will continue to function as a living innovation ecosystem, supporting the long-term evolution, deployment, and scaling of V2X-based solutions beyond the project lifetime.

7 Conclusions

Innovation management within European research and innovation projects requires a comprehensive understanding of market, legal, social, and technical dimensions, with the objective of transforming creative ideas into implementable and exploitable solutions. Within EV4EU, a dedicated and well-structured innovation management process was defined from the early-stage of the project to ensure coherence between research challenges, validation activities, user needs, and exploitation pathways.

The EV4EU project was driven by the ambition to achieve a significant and lasting impact through the implementation of bottom-up and user-centric V2X management strategies, creating the conditions for the large-scale deployment of electric vehicles as active components of the energy system. To support this ambition, the innovation strategy was designed at project inception and continuously refined throughout the project lifecycle. This strategy acted as both a guiding framework and an operational tool, ensuring alignment between work packages, demonstrators, and exploitation objectives. As such, the innovation strategy functioned as an adaptive, living document, evolving in response to project progress, feedback, and external developments.

Over the course of the project, EV4EU implemented a comprehensive and systematic innovation management process, resulting in the identification, analysis, and structuring of 113 distinct innovations. These innovations were analysed using a structured innovation funnel, open innovation principles, and clearly defined evaluation criteria. Each innovation was assessed from multiple perspectives, including technical maturity, user relevance, regulatory feasibility, and market potential.

The resulting innovation landscape proved to be rich, diverse, and multi-layered, spanning technical solutions, digital tools, business models, user-centric services, and regulatory or organisational concepts. This diversity confirms that successful, large-scale V2X deployment requires interconnected and multidisciplinary solutions, rather than isolated technological advances.

The innovation funnel approach proved highly effective, as the majority of identified innovations progressed successfully through the evaluation process. Promising ideas were strengthened and refined, while those misaligned with project objectives were filtered out early, ensuring an efficient allocation of project resources and a high overall quality of results. The classification of innovations into basic, sustaining, breakthrough, and disruptive categories further demonstrated that EV4EU achieved a balanced innovation portfolio, combining incremental improvements with high-impact and transformative solutions.

A key observation was that the strongest and most mature innovations emerged from intensive cross-partner collaboration, where technical expertise was combined with user insights, operational data from demonstrators, and regulatory considerations. The application of open innovation principles significantly enhanced innovation quality by integrating complementary perspectives from multiple partners, demonstration sites, and stakeholder groups.

Overall, the EV4EU innovation management process proved to be robust, transparent, and highly effective. It not only enabled the systematic handling of a large and complex innovation portfolio, but also created a solid baseline for post-project exploitation and continued development. The structured evaluation, typology classification, and funnel-based filtering provide a clear foundation for further scaling, market uptake, and follow-up innovation activities beyond the project duration.

In this sense, innovation management within EV4EU was not merely a reporting or coordination exercise, but a core success factor of the project, ensuring that ideas were transformed into structured, validated, and exploitation-ready outcomes with long-term impact potential.

8 Bibliography

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9 APPENDIX

9.1 Innovation portfolio – Denmark

Innovation	Description	Owner/Leader(s)	Involved entities/main players	Ownership and IP strategy maturity	TRL	IRL	Category	Sub-category
Algorithms Load management charger	Algorithms Load management charger.	DTU	DTU	IPR and ownership defined	5	6	Tools	Decision-focused
Backend architecture	Backend architecture.	Circle	Circle	IPR and ownership defined	8	7	Tools	Operation-focused
CAD chargers design	CAD chargers design.	Circle	Circle	IPR and ownership defined	8	7	Tools	Operation-focused
Chargers' hardware	Chargers' hardware.	Circle	Circle	IPR and ownership defined	8	7	Tools	Operation-focused
Control algorithm	Control algorithm.	DTU	DTU	IPR and ownership defined	5	6	Tools	Operation-focused
Data logging and visualization	Data logging and visualization.	DTU	DTU	IPR and ownership defined	9	6	Tools	Operation-focused

Demand Response for V2X	The DSO establishes a demand response (DR) market where it procures flexibility capacity from V2X (V2G) technology aggregation. To enable their participation, the DSO implements appropriate technical and market mechanisms that allow end-users to engage in the market through an aggregator, in accordance with the constraints of the local distribution network. The solution fosters large-scale EV integration while supporting power system flexibility, and leverages on advanced strategies to enable EVs to actively contribute as distributed energy resources, engaging end-users, fleet operators, and aggregators in new flexibility services. These programs aim to reduce peak demand, ease grid constraints, and facilitate higher renewable integration, all while preserving user comfort and long-term system sustainability.	Circle, DTU	-R&D Centre/University/CoLAB (Circle, DTU) -DSO (BEOF)	IPR and ownership defined	6	8	Business Models and Services	Grid services
Firmware design	Firmware design.	Circle	Circle	IPR and ownership defined	9	6	Tools	Operation-focused
Flexible services for local market	Aggregator can coordinate different parking lots to access flexibility services markets and bid flexibility services. The larger flexibility coming from an aggregation of parking lots could be marketed and provide revenue streams.	DTU	-R&D Centre/University/CoLAB (DTU)	IPR and ownership defined	7	8	Business Models and Services	Grid services
Green charging	Maximising, ensuring and incentivising the coordination between EV charging and discharging (V2X) and the RES curtailment, specifically wind curtailment, at a distribution level. DSOs (or TSOs) identifies abundant power generation from distributed RES and provides incentives for EVs to adjust their charging decisions to make use of this green energy.	DTU	-R&D Centre/University/CoLAB (Circle, DTU, CB) -DSO (BEOF)	IPR and ownership defined	6	8	Business Models and Services	Grid services

Houses/Building/Parking Lot energy management system	Energy management system which with inputs from building/house energy meter can monitor and adapt the EV charger consumption depending on the consumption of the building. This allows to setup EV chargers, even if in peak periods building/house consumption is close to fuse limit. It aligns energy flows between EVs, building loads, and the grid to improve self-consumption and overall value, enabling bidirectional operation where supported. This solution can also be applicable and scalable to parking lots.	DTU	-R&D Centre/University/CoLAB (Circle, DTU, CB)	IPR and ownership defined	7	8	Technologies	Multi-asset
Load balancing smart charger (New)	Smart charging station with the opportunity to perform load balancing, meaning if one of the phases is heavily loaded in the grid the algorithm can compensate for this, and choose to reduce or increase the consumption. The algorithms enable receiving local signals about grid loading, similar to demand response but on local level to allow charging operators to reduce current on selected phases (it may be required for EV owners to have their EV charging on a phase different from the grid locally).	Circle	-R&D Centre/University/CoLAB (Circle, DTU, CB)	IPR and ownership defined	7	8	Technologies	EV-focused
PCB Design	PCB Design.	Circle	Circle	IPR and ownership defined	8	7	Tools	Operation-focused
Phone app (iOS/android)	Phone app (iOS/android).	Circle	Circle	IPR and ownership defined	8	7	Tools	Operation-focused
Prioritization algorithm	Prioritization algorithm.	Circle	Circle	IPR and ownership defined	9	6	Tools	Operation-focused

Sharing charging	Business model based on a smart load management system that enables multiple EVs to charge simultaneously, even when local electrical capacity is limited. Instead of costly grid upgrades or restricting access, it dynamically allocates available power based on real-time factors like grid capacity, battery state of charge, departure time, electricity pricing, and safety limits. It can be particularly suitable for companies operating EV fleets that also share V2X charging stations with employees and visitors. It incorporates a dynamic prioritization hierarchy across fleet vehicles, employees, visitors and facility services. The system also enables energy redistribution among vehicles, to maximize the number of EVs simultaneously charging while optimizing overall energy usage and user satisfaction. The charging system can provide power sharing and power scheduling functionalities to have the EVs modulating or pausing their charging sessions - this technology will enable the chargers to perform advanced shared charging services to be utilized by CPOs.	DTU	-R&D Centre/University/CoLAB (Circle, DTU, CB)	IPR and ownership defined	5	8	Business Models and Services	User-focused services
V2X Station	Charging station equipped with Vehicle-to-Everything technology, which enables EV charging and discharging for grid enhancing and local flexibility tasks. It also allows to charge multiple Evs simultaneously.	Circle	-R&D Centre/University/CoLAB (Circle)	IPR and ownership defined	5	8	Technologies	EV-focused
Web interface	Web interface.	Circle	Circle	IPR and ownership defined	5	3	Tools	Operation-focused

9.2 Innovation portfolio – Greece

Innovation	Description	Owner/Leader(s)	Involved entities/main players	Ownership and IP strategy maturity	TRL	IRL	Category	Sub-category
Algorithms for Time estimation for routing and charging	Algorithms for Time estimation for routing and charging .	PPC	PPC	IPR and ownership defined	5	6	Tools	Decision-focused
Algorithms for Calculation of variable grid tariffs	Algorithms for Calculation of variable grid tariffs.	HEDNO	HEDNO	IPR and ownership defined	6	7	Tools	Decision-focused
Algorithms for learning charging curves per EV from past charging sessions	Algorithms for learning charging curves per EV from past charging sessions.	PPC	PPC	IPR and ownership defined	5	6	Tools	Operation-focused
Algorithms for predicting day-ahead demand per EV charger	Algorithms for predicting day-ahead demand per EV charger.	PPC	PPC	IPR and ownership defined	5	6	Tools	Operation-focused
Algorithms for Real time monitoring and management of EV chargers	Algorithms for Real time monitoring and management of EV chargers.	PPC	PPC	IPR and ownership defined	5	6	Tools	Decision-focused
Decision Support Tools for VPPs and CPOs	Tools supporting the decision-making for VPPs and CPOs, allowing the activation of flexibilities available at each moment in the network, and supporting real-time EV charging coordination, charging network expansion and V2G services potential. The tools should be integrated into the management systems operated by CPO or VPP operator.	PPC	PPC	IPR and ownership defined	5	8	Tools	Decision-focused

Design - Capacity Limit Contracts	Design - Capacity Limit Contracts.	HEDNO	HEDNO	IPR and ownership defined	5	6	Business Models and Services	EV-focused
Design - Green charging	Design - Green charging.	HEDNO	HEDNO	IPR and ownership defined	5	6	Business Models and Services	EV-focused
DSS tool - Real time interoperability with other exogenous platforms (CPO platforms)	DSS tool - Real time interoperability with other exogenous platforms (CPO platforms).	HEDNO	HEDNO	IPR and ownership defined	5	6	Tools	Operation-focused
DSS tool - Real time monitoring of Distribution Systems	DSS tool - Real time monitoring of Distribution Systems.	HEDNO	HEDNO	IPR and ownership defined	5	6	Tools	Operation-focused
Feature for providing estimated day-ahead demand per EV charger	This feature provides day-ahead volume consumption estimates for each charging site by leveraging historical charging curves, session data, and demand patterns. The system employs an ensemble of specialized forecasting models (LSTM, XGBoost, ARIMA) trained individually per charging site to deliver robust, site-specific predictions while maintaining granular demand and charging volume accuracy.	PPC	PPC	IPR and ownership defined	5	4	Tools	CPO planning service
Feature of Time estimation for routing and charging	Both CPOs and EV Users get incentives for both arrival time and the charging session's duration, based on the current capacity levels of the selected charging site and the needed amount of kW.	PPC	PPC	IPR and ownership defined	5	4	Tools	User-focused Service
Flexible capacity contracts for V2X	Flexibility capacity contracts enable electric vehicle owners and fleet operators to provide grid support services by making their EV batteries available for bidirectional charging (V2X). Through these contracts, stakeholders agree to provide a defined amount of flexible charging/discharging capacity that can be activated when needed for grid stability and balancing. PPC's contribution to this ecosystem lies in developing and operating advanced V2G (Vehicle-to-Grid) and V1G (Vehicle-to-One-way-Grid) smart management systems through the O-V2X-MP platform, which enables	PPC	-Utility (PPC)	IPR and ownership defined	7	7	Business Models and Services	Grid services

	intelligent coordination of EV charging and discharging to optimize both grid operations and user satisfaction while ensuring battery health and operational constraints are respected.							
Green charging	Maximising, ensuring and incentivising the coordination between EV charging and discharging (V2X) and the RES curtailment, specifically wind curtailment, at a distribution level. DSOs (or TSOs) identifies abundant power generation from distributed RES and provides incentives for EVs to adjust their charging decisions to make use of this green energy.	HEDNO, PPC	-Utility (PPC) -DSO (HEDNO)	IPR and ownership defined	7	7	Business Models and Services	Grid services
Integration of V2X management in DMS	Tools integrating V2X algorithms within a Distribution Management System (integrated software suite) which embed EVs and their charging stations into the utility's real-time operational framework. By treating EVs as bidirectional, grid-interactive resources rather than passive loads, the DMS can incentivize charging/discharging to stabilize voltage profiles, alleviate feeder congestion and provision/request ancillary services.	HEDNO	-DSO (HEDNO)	IPR and ownership defined	7	7	Tools	Operation-focused
LV monitoring (New) (HW and SW)	An LV (Low-Voltage) Monitoring System for a DSO is an integrated solution that continuously (real-time) measures, collects and analyses electrical parameters at the low-voltage level (typically up to 1 kV) on the distribution network. Its primary goal is to give the DSO real-time visibility into what's happening at the "last mile" of their grid. The LV monitoring system consists of the field measurement devices (hardware) and all the technologies (software) that cooperate to seamlessly transfer and store the data from the field to the databases and platforms.	HEDNO	-DSO (HEDNO)	IPR and ownership defined	8	8	Technologies	Grid-focused
Modelling of EV user charging behaviour	Modelling of EV user charging behaviour.	HEDNO	HEDNO	IPR and ownership defined	6	7	Tools	Operation-focused
Novel design for overarching homogenization system (DSS)	Novel design for overarching homogenization system (DSS) of heterogenous legacy systems.	HEDNO	HEDNO	IPR and ownership defined	5	6	Tools	Operation-focused
Open V2X management platform	Platform to support the next generation of V2X, supplying the user's needs and increasing their engagement with the V2X service, allowing the information exchange between end-users, operators, and systems.	PPC	Utility (PPC)	IPR and ownership defined	8	8	Tools	Operation-focused

O-V2X-MP - Intuitive GUI for EV users and CPOs	O-V2X-MP - Intuitive GUI for EV users and CPOs.	PPC	PPC	IPR and ownership defined	5	6	Tools	Operation-focused
O-V2X-MP - Real time connection with DSS	O-V2X-MP - Real time connection with DSS.	PPC	PPC	IPR and ownership defined	5	6	Technologies	Grid-focused
O-V2X-MP - Real time notifications	With Real time connection between DSS and O-V2X-MP, the platform provides real time notifications for both CPOs and EV Users to get incentives for the charging prices per charging site compared to before-and-after tariffs.	PPC	PPC	IPR and ownership defined	5	6	Technologies	EV-focused
O-V2X-MP - Weather forecasting and visualization	O-V2X-MP - Weather forecasting and visualization.	PPC	PPC	IPR and ownership defined	5	6	Technologies	Operation-focused
O-V2X-MP V2G interfaces	Monitoring and management of V2G functionality for V2G enabled charging stations.	PPC	PPC	IPR and ownership defined	5	7	Technologies	Operation-focused
Plug & play integration	Plug & play integration of third-party procedures and processes.	HEDNO	HEDNO	IPR and ownership defined	7	7	Tools	Operation-focused
Transformer Loading Forecasting Algorithm	Designed and implemented a customized SARIMA time-series forecasting model to predict transformer apparent power. The model provides now real-time, continuous predictions.	DTU	DTU, HEDNO	IPR and ownership defined	8	7	Tools	Operation-focused
Triggering & Real-Time Monitoring Algorithm	Developed a trigger framework that detects and flags predicted transformer overloads based on forecast outputs. Defined severity levels and corresponding response actions, ranging from implicit incentives (dynamic tariff signals) to explicit interventions (capacity caps).	DTU	DTU, HEDNO	IPR and ownership defined	8	7	Tools	Operation-focused

9.3 Innovation portfolio – Portugal

Innovation	Description	Owner/Leader(s)	Involved entities/main players	Ownership and IP strategy maturity	TRL	IRL	Category	Sub-category
Business analysis of flexibility services	Differences between common practices (buy in futures) VS buying in real time.	INESC-ID	INESC-ID	IPR and ownership defined	5	5	Business Models and Services	Decision-focused
Co-simulation platform for V2X	Tools designed to assist experts in planning a municipality's electric infrastructure, specifically focusing on the optimal locations and characteristics of EV chargers, and also allowing for the simulation of V2X management strategies - simulating and evaluating V2G EVs flexibility potential and their capability for participation in local flexibility services, while also ensuring that user requirements are met. It enables simulation of energy grid and road traffic, as EVs and V2G technology are in mass use. Users can specify a few essential parameters for the simulation, such as the geographical area under study, the total number of vehicles in circulation, and local grid information (if available), among other relevant factors.	INESC-ID	-R&D Centre/University/CoLAB (INESC-ID, SEL) -DSO (EDA)	IPR and ownership defined	5	8	Tools	Decision-focused
Cost-effective bidirectional charging station developed	CS tested in the Demos.	SEL	SEL	IPR and ownership defined	7	6	Technologies	EV-focused
Demand Response for V2X	The DSO establishes a demand response (DR) market where it procures flexibility capacity from V2X (V2G) technology aggregation. To enable their participation, the DSO implements appropriate technical and market mechanisms that allow end-users to engage in the market through an aggregator, in accordance with the constraints of the local distribution network.	INESC-ID	-R&D Centre/University/CoLAB (INESC-ID, SEL) -DSO (EDA) -Regional government (DRE) -Utility (EDP New)	IPR and ownership defined	5	8	Business Models and Services	Grid services

	The solution fosters large-scale EV integration while supporting power system flexibility, and leverages on advanced strategies to enable EVs to actively contribute as distributed energy resources, engaging end-users, fleet operators, and aggregators in new flexibility services. These programs aim to reduce peak demand, ease grid constraints, and facilitate higher renewable integration, all while preserving user comfort and long-term system sustainability.							
Development of user interface app for EV users	User friendly interface app.	INESC-ID	INESC-ID	IPR and ownership defined	7	6	Tools	User-focused services
EV Fleet Management Services	Companies using the developed algorithms allowing the optimal management of EVs considering travel and charging needs. The digital solution coordinates SME EV fleet usage and charging across facilities. It aligns mobility needs with site electrical capabilities to boost vehicle availability while reducing infrastructure spend and contracted power.	INESC-ID	-R&D Centre/University/CoLAB (INESC-ID) -Utility (EDP New)	IPR and ownership defined	7	8	Business Models and Services	User-focused services
EV user engagement methods	Through WhatsApp and surveys – innovative ways of collecting EV user's feedback.	SEL	SEL	IPR and ownership defined	8	7	Tools	User-focused services
Green charging	Maximising, ensuring and incentivising the coordination between EV charging and discharging (V2X) and the RES curtailment, specifically wind curtailment, at a distribution level. DSOs (or TSOs) identifies abundant power generation from distributed RES and provides incentives for EVs to adjust their charging decisions to make use of this green energy.	INESC-ID	-R&D Centre/University/CoLAB (INESC-ID, SEL) -DSO (EDA) -Regional government (DRE) -Utility (EDP New)	IPR and ownership defined	5	8	Business Models and Services	Grid services

Houses/Building/Parking Lot energy management system	Energy management system which with inputs from building/house energy meter can monitor and adapt the EV charger consumption depending on the consumption of the building. This allows to setup EV chargers, even if in peak periods building/house consumption is close to fuse limit. It aligns energy flows between EVs, building loads, and the grid to improve self-consumption and overall value, enabling bidirectional operation where supported. This solution can also be applicable and scalable to parking lots.	INESC-ID	-R&D Centre/University/CoLAB (INESC-ID, SEL) -Utility (EDP New)	IPR and ownership defined	7	8	Technologies	Multi-asset
Load balancing techniques - business POV	Lower contracted power by companies with a fleet, reduced installation costs. (Fleet management business case)	INESC-ID	INESC-ID	IPR and ownership defined	5	4	Business Models and Services	Decision-focused
Load balancing techniques - technical POV	Techniques such as not using all the contracted power, optimally sharing it between all EV CS. (Fleet management business case)	INESC-ID	INESC-ID	IPR and ownership defined	5	4	Technologies	EV-focused
Multi-OEM cloud- and edge computing-based integration	Architecture enabling interoperability between multiple EVSE OEMs through a combined cloud–edge design.	INESC-ID	INESC-ID	IPR and ownership defined	6	6	Technologies	Multi-asset
Participation of V2X in markets and services	Aggregators allowing the participation of V2X in energy markets and services (ancillary services and services procured by DSOs). Consumers, producers, and storage owners can adjust energy use/supply to support the grid. Aggregator pool EVs and batteries to offer flexibility to DSOs, helping balance demand, reduce congestion, and avoid grid upgrades. Users earn incentives; TSOs and DSOs gain stability and more renewables penetration.	INESC-ID	-R&D Centre/University/CoLAB (INESC-ID, SEL) -DSO (EDA) -Regional government (DRE) -Utility (EDP New)	IPR and ownership defined	8	8	Business Models and Services	Grid services
Platform to find the optimal location for an EV charging station	Considering traffic, load profiles.	INESC-ID	INESC-ID	IPR and ownership defined	5	5	Tools	Operation-focused
Real use-case testing (incl. battery degradation studies)	Analysis of the impact of charging and discharging sessions on battery degradation.	EV4EU	EV4EU	IPR and ownership defined	6	6	Technologies	EV-focused

Regulatory directions for TSO and business insights (in "Green" charging)	New players as aggregators, do not exist in the PT reality, needed for green charging.	INESC-ID	INESC-ID	IPR and ownership defined	3	4	Business Models and Services	Grid services
Sharing charging	Business model based on a smart load management system that enables multiple EVs to charge simultaneously, even when local electrical capacity is limited. Instead of costly grid upgrades or restricting access, it dynamically allocates available power based on real-time factors like grid capacity, battery state of charge, departure time, electricity pricing, and safety limits. It can be particularly suitable for companies operating EV fleets that also share V2X charging stations with employees and visitors. It incorporates a dynamic prioritization hierarchy across fleet vehicles, employees, visitors and facility services. The system also enables energy redistribution among vehicles, to maximize the number of EVs simultaneously charging while optimizing overall energy usage and user satisfaction. The charging system can provide power sharing and power scheduling functionalities to have the EVs modulating or pausing their charging sessions - this technology will enable the chargers to perform advanced shared charging services to be utilized by CPOs.	INESC-ID	-R&D Centre/University/CoLAB (INESC-ID) -DSO (EDA) -Utility (EDP New)	IPR and ownership defined	5	8	Business Models and Services	User-focused services
Smart charging and discharging algorithms developed	Optimization algorithms (daily planning stage plus real-time operation) were validated in real environment.	INESC-ID	INESC-ID	IPR and ownership defined	7	6	Technologies	EV-focused
Study/data on EV user profiles	Data collected on different types of EV users (private, business, fleet).	INESC-ID	INESC-ID	IPR and ownership defined	7	6	Business Models and Services	User-focused services
V2X Station	Charging station equipped with Vehicle-to-Everything technology, which enables EV charging and discharging for grid enhancing and local flexibility tasks. It also allows to charge multiple Evs simultaneously.	SEL	-R&D Centre/University/CoLAB (INESC-ID, SEL)	IPR and ownership defined	8	8	Technologies	EV-focused

9.4 Innovation portfolio – Slovenia

Innovation	Description	Owner/Leader(s)	Involved entities/main players	Ownership and IP strategy maturity	TRL	IRL	Category	Sub-category
Additional functionalities of ADMS (additional services)	Upgrade of the ADMS with additional functionalities, related to the forecasting of production and consumption of electrical energy. Additionally, activation forecasting, activation signal service was also procured.	EC	EC	IPR and ownership defined	8	8	Technologies	Grid-focused
Additional functionalities of ADMS (additional services)	Upgrade of the ADMS with additional functionalities, related to the forecasting of production and consumption of electrical energy. Additionally, activation forecasting, activation signal service was also procured.	EC	EC	IPR and ownership defined	8	8	Tools	Decision-focused
Aggregated representative EV profiles	Statistical EV profiles with V2G emulate realistic mobility, market, and grid data.	UL, GEN-I, ELCE	GEN-I, UL, ELCE	IPR and ownership defined	9	9	Tools	Decision-focused
Analyses of the EVs-V2G impact on the grid	We made the analysis of the impact V2G EV's on the distribution grid.	EC, UL, GEN-I	EC, UL, GEN-I	IPR and ownership defined	7	7	Tools	Operation-focused
BESS demonstrator KPI analysis support tool	The KPI Tool is an Excel-based software solution developed as part of the Slovenian demonstrator of the EV4EU project to monitor and evaluate key performance indicators (KPIs) for the BESS demonstrator in Velenje.	UL	-Aggregator (GEN-I) -DSO (Elektro Celje) -Technology provider (ABB)	IPR and ownership defined	5	5	Tools	Decision-focused
Business model for EVs owners	In order to motivate users to participate in V2X activities, a business model that will motivate users is key. The business model itself, which will be upgraded and launched on the market in the future, was developed within the project.	GEN-I	GEN-I	IPR and ownership defined	8	8	Business Models and Services	EV-focused

Business model for EVs V2X	The integration of EVs into flexibility capacity represents an expansion of the flexibility offering. This represents changes in the market on the one hand, and on the other hand, a key upgrade of the business model.	GEN-I	GEN-I	IPR and ownership defined	8	8	Business Models and Services	EV-focused
Co-simulation platform for V2X	Tools designed to assist experts in planning a municipality's electric infrastructure, specifically focusing on the optimal locations and characteristics of EV chargers, and also allowing for the simulation of V2X management strategies - simulating and evaluating V2G EVs flexibility potential and their capability for participation in local flexibility services, while also ensuring that user requirements are met. It enables simulation of energy grid and road traffic, as EVs and V2G technology are in mass use. Users can specify a few essential parameters for the simulation, such as the geographical area under study, the total number of vehicles in circulation, and local grid information (if available), among other relevant factors.	UL	-Aggregator (GEN-I) -DSO (Elektro Celje) -R&D Centre/University/CoLAB (UL)	IPR and ownership defined	8	8	Tools	Decision-focused
Data exchange based on CIM standard	A system for exchanging messages between GEN-I and EVT (Tool in Technologies) was developed within the framework of the project.	GEN-I	GEN-I	IPR and ownership defined	8	8	Technologies	EV-focused
Decision Support Tools for VPPs and CPOs	Tools supporting the decision-making for VPPs and CPOs, allowing the activation of flexibilities available at each moment in the network, and supporting real-time EV charging coordination, charging network expansion and V2G services potential. The tools should be integrated into the management systems operated by CPO or VPP operator.	GEN-I	-Aggregator (GEN-I) -DSO (Elektro Celje) -R&D Centre/University/CoLAB (UL)	IPR and ownership defined	8	8	Tools	Decision-focused

Decision Support Tools for VPPs and CPOs	Tools supporting the decision-making for VPPs and CPOs, allowing the activation of flexibilities available at each moment in the network, and supporting real-time EV charging coordination, charging network expansion and V2G services potential. The tools should be integrated into the management systems operated by CPO or VPP operator.	UL	-Aggregator (GEN-I) -DSO (Elektro Celje) -R&D Centre/University/CoLAB (UL)	IPR and ownership defined	5	7	Tools	Decision-focused
Demand Response for V2X	The DSO establishes a demand response (DR) market where it procures flexibility capacity from V2X (V2G) technology aggregation. To enable their participation, the DSO implements appropriate technical and market mechanisms that allow end-users to engage in the market through an aggregator, in accordance with the constraints of the local distribution network. The solution fosters large-scale EV integration while supporting power system flexibility, and leverages on advanced strategies to enable EVs to actively contribute as distributed energy resources, engaging end-users, fleet operators, and aggregators in new flexibility services. These programs aim to reduce peak demand, ease grid constraints, and facilitate higher renewable integration, all while preserving user comfort and long-term system sustainability.	Elektro Celje	-DSO (Elektro Celje) -Aggregator (GEN-I) -Technology provider (ABB) -R&D Centre/University/CoLAB (UL)	IPR and ownership defined	7	8	Business Models and Services	Grid services
Demonstrator based V2GFlex flexibility tool	V2GFlex tool simulates and evaluates flexibility potential of EVs and estimates the potential use of V2G EV flexibility for a model corresponding to Slovenian demonstrator with the aim of participating in local services and consequently enabling EVs to take part in the flexibility market, while also ensuring that user requirements are met. It enables simulation of energy grid and road traffic for Slovenian demonstrator as EVs and V2G	UL	-DSO (Elektro Celje) -Aggregator (GEN-I) -Technology provider (ABB)	IPR and ownership defined	5	5	Tools	Decision-focused

	technology are in mass use. Results of the tool are based on real input data.							
Development of Local Market Platform with extension for E-Mobility - FLEXIS	System for purchasing flexibility services for DSO on the local market.	EC, EIMV	EC, EIMV	IPR and ownership defined	5	5	Tools	Operation -focused
Development of new algorithm for EVs participation in flexibility market	EVs represent an important source of flexibility, which in the long-term can significantly increase the flexibility capacities in the market. The development of the initial advanced algorithms itself represents the basis for long-term development. Wherein, future development will be based primarily on user behaviour and needs in the flexibility market, and various new flexibility services that will be developed in the future.	GEN-I	GEN-I	IPR and ownership defined	7	7	Tools	Operation -focused
Development of the tool to the emulation of EVs supporting V2G and related to the flexibility services	Tool that emulates EVs supporting V2G, related to the flexibility services.	GEN-I, Elektro Celje, UL	GEN-I, Elektro Celje, UL	IPR and ownership defined	8	8	Tools	Operation -focused
Development of flexibility market in Slovenia	Development of local flexibility market for purchasing and selling flexibility service on local flexibility market for DSO,TSO, aggregators and end users.	EC, GEN-I	EC, GEN-I	IPR and ownership defined	7	7	Business Models and Services	Operation -focused
EV aggregation model for flexibility assessment	An EV aggregation model enabling scenario-based simulations under historically observed, use-case- and location-specific operating conditions, aggregating vehicle-level behaviour into VPP-ready flexibility products and providing decision-support insights for aggregators and CPOs.	UL	-Aggregator (GEN-I) -DSO (Elektro Celje)	IPR and ownership defined	7	7	Tools	Decision-focused

EV Fleet Management Services	Companies using the developed algorithms allowing the optimal management of EVs considering travel and charging needs. The digital solution coordinates SME EV fleet usage and charging across facilities. It aligns mobility needs with site electrical capabilities to boost vehicle availability while reducing infrastructure spend and contracted power.	GEN-I	-Aggregator (GEN-I) -Technology provider (ABB) -DSO (Elektro Celje) -R&D Centre/University/CoLAB (UL)	IPR and ownership defined	7	8	Business Models and Services	User-focused services
EV user profiles	EV vehicle profiles that will be used for simulations in the event of a larger number of such users.	GEN-I, UL, ELCE	GEN-I UL, ELCE	IPR and ownership defined	8	8	Tools	Operation -focused
EVs V2X Profiles	Analysis of EV user profiles provides a basis for understanding owner behaviour. V2X will include EV owners in the flexibility we will offer in the market. Understanding user behaviour is key to determining capacity.	GEN-I	GEN-I	IPR and ownership defined	8	8	Tools	Operation -focused
Flexibility from V2X EVs	New service. A new service on the DSO and TDO flexibility market in Slovenia. This service will enable reliable network operation as flexibility capacities will increase due to the integration of EVs. In the first phase, this may represent an EV management service, while as V2X becomes more widely available on the market, it will be further expanded with the integration of V2X EVs.	GEN-I	GEN-I	IPR and ownership defined	8	8	Business Models and Services	Grid services
Flexible capacity contracts for V2X	Flexibility capacity contracts for Vehicle-to-Everything (V2X) enable Distribution System Operators (DSOs) or aggregators to procure defined amounts of flexibility from EV owners and fleet operators. These contracts specify the available capacity that can be activated on demand to support grid balancing, congestion management, or ancillary services. Such contracts are primarily established with key stakeholders including aggregators, Charge Point	GEN-I	-Aggregator (GEN-I) -Technology provider (ABB) -DSO (Elektro Celje) -R&D Centre/University/CoLAB (UL)	IPR and ownership defined	8	8	Business Models and Services	Grid services

	Operators (CPOs), and large fleet operators. The contracts define conditions under which V2X-enabled assets, such as EVs or stationary storage, adjust their charging or discharging behaviour in response to grid capacity constraints or flexibility requests.							
Flexible services for local market	Aggregator can coordinate different parking lots to access flexibility services markets and bid flexibility services. The larger flexibility coming from an aggregation of parking lots could be marketed and provide revenue streams.	GEN-I	-Aggregator (GEN-I) -Technology provider (ABB) -DSO (Elektro Celje) -R&D Centre/University/CoLAB (UL)	IPR and ownership defined	8	8	Business Models and Services	Grid services
Forecast algorithm for the flexibility assessment	EVs represent an important source of flexibility, which in the long-term can significantly increase the flexibility capacities in the market. Forecasting the location of flexibility will be key to determining capacities. A basic model was developed within the project.	GEN-I	GEN-I	IPR and ownership defined	6	6	Tools	Operation -focused
Green charging	Maximising, ensuring and incentivising the coordination between EV charging and discharging (V2X) and the RES curtailment, specifically wind curtailment, at a distribution level. DSOs (or TSOs) identifies abundant power generation from distributed RES and provides incentives for EVs to adjust their charging decisions to make use of this green energy.	GEN-I	-Aggregator (GEN-I) -Technology provider (ABB) -DSO (Elektro Celje) -R&D Centre/University/CoLAB (UL)	IPR and ownership defined	8	8	Business Models and Services	Grid services
Innovative use of BESS for emulation of EVs supporting V2G	VPP activation of aggregated representative EV profiles on a BESS, which consequently emulates EVs.	GEN-I, Elektro Celje, UL	GEN-I, Elektro Celje, UL	IPR and ownership defined	8	8	Technologies	Multi-asset

Integration of V2X management in DMS	Tools integrating V2X algorithms within a Distribution Management System (integrated software suite) which embed EVs and their charging stations into the utility's real-time operational framework. By treating EVs as bidirectional, grid-interactive resources rather than passive loads, the DMS can incentivize charging/discharging to stabilize voltage profiles, alleviate feeder congestion and provision/request ancillary services.	GEN-I	-Aggregator (GEN-I) -DSO (Elektro Celje) -R&D Centre/University/CoLA B (UL)	IPR and ownership defined	8	8	Tools	Operation -focused
KPI-based evaluation methodology for V2X demonstrators	A comprehensive methodology for the development, evaluation, and analysis of KPIs tailored to V2X demonstrators, enabling consistent performance assessment across technical, economic, environmental and social layers.	UL, GEN-I, EC	EC,GEN-I, ABB	IPR and ownership defined	8	8	Business Models and Services	Grid-focused
Management of CSs portfolio (CPO management system for parking lot operation)	The management system enables monitoring of the parking lot, as well as management of the charging infrastructure. This allows monitoring of V2X charging stations, as well as receiving information about the state of the car's battery.	GEN-I	GEN-I	IPR and ownership defined	8	8	Tools	Operation -focused
Methodology for BM	Multi actor business model.	UL, GEN-I, EC	EC,GEN-I, ABB	IPR and ownership defined	9	8	Business Models and Services	Grid-focused
Open V2X management platform	Platform to support the next generation of V2X, supplying the user's needs and increasing their engagement with the V2X service, allowing the information exchange between end-users, operators, and systems.	GEN-I	-Aggregator (GEN-I) -Technology provider (ABB) -DSO (Elektro Celje) -R&D Centre/University/CoLA B (UL)	IPR and ownership defined	5	8	Tools	Operation -focused

Participation of V2X in markets and services	Aggregators allowing the participation of V2X in energy markets and services (ancillary services and services procured by DSOs). Consumers, producers, and storage owners can adjust energy use/supply to support the grid. Aggregator pool EVs and batteries to offer flexibility to DSOs, helping balance demand, reduce congestion, and avoid grid upgrades. Users earn incentives; TSOs and DSOs gain stability and more renewables penetration.	GEN-I	-DSO (Elektro Celje) -Aggregator (GEN-I) -Technology provider (ABB) -R&D Centre/University/CoLAB (UL)	IPR and ownership defined	8	8	Business Models and Services	Grid services
Real-EV Testing of EV Profiles / Testing of EV profiles on EVs	Testing of selected aggregated representative EV profiles on Evs.	GEN-I,UL, ELCE	GEN-I, UL, ELCE	IPR and ownership defined	7	7	Tools	Decision-focused
Sharing charging	Business model based on a smart load management system that enables multiple EVs to charge simultaneously, even when local electrical capacity is limited. Instead of costly grid upgrades or restricting access, it dynamically allocates available power based on real-time factors like grid capacity, battery state of charge, departure time, electricity pricing, and safety limits. It can be particularly suitable for companies operating EV fleets that also share V2X charging stations with employees and visitors. It incorporates a dynamic prioritization hierarchy across fleet vehicles, employees, visitors and facility services. The system also enables energy redistribution among vehicles, to maximize the number of EVs simultaneously charging while optimizing overall energy usage and user satisfaction. The charging system can provide power sharing and power scheduling functionalities to have the EVs modulating or pausing their charging sessions - this technology will enable the chargers to perform advanced	GEN-I	-Aggregator (GEN-I) -Technology provider (ABB)	IPR and ownership defined	8	8	Business Models and Services	User-focused services

	shared charging services to be utilized by CPOs.							
Software for the communication module in V2X CS	In line with ISO standard ISO 15118-20.	ABB	ABB	IPR and ownership defined	8	8	Technologie s	EV-focused
Space-time modelling of local traffic	Space-time modelling integrating EV mobility patterns with real distribution grid topology to quantify city-level charging impacts (power/energy demand), with model validation based on statistical and historical data and applicability beyond the demonstrator scope.	UL	-Aggregator (GEN-I) -DSO (Elektro Celje) -Technology provider (ABB)	IPR and ownership defined	7	7	Tools	Operation -focused
System for managing end users' assets (VPP)	System ensured is the automatic activation of the components included inti our capacities for flexibility market. The system enables us also the activation of the components (V2X charging stations).	GEN-I	GEN-I	IPR and ownership defined	8	8	Tools	Operation -focused
System for the management of GEN-I's portfolio	The system enables the integration of various sources of flexibility, which allows GEN-I to select the most optimal portfolio.	GEN-I	GEN-I	IPR and ownership defined	8	8	Tools	Operation -focused
System for the message exchange and activation messages	System for exchanging messages between DSO, VPP, Market platform.	EIMV, EC, GEN-I	EIMV, EC, GEN-I	IPR and ownership defined	8	7	Technologie s	EV-focused
Tool for contract management	The tool allows for the generation, electronic and manual signing of contracts.	EIMV, EC	EIMV, EC	IPR and ownership defined	7	7	Tools	Operation -focused
Traffic light system	TLS is system for the signalization of limitations on the distribution gird, for the TSO, Energy suppliers.	EIMV	EIMV	IPR and ownership defined	5	5	Technologie s	Grid-focused
Upgrade of the communication module in V2X CS	Advanced V2X charging station.	ABB	ABB	IPR and ownership defined	8	8	Technologie s	EV-focused
Upgrade of unified entry point (EVT)	Development of additional functionalities of unified entry point (EVT) that enables participation of DSOs, TSOs, end users, aggregators on local flexibility market.	Informatika d.o.o., EC,EIMV	Informatika d.o.o., EC,EIMV	IPR and ownership defined	6	6	Tools	Operation -focused

V2X CSs prototype	Development of the state-of-the-art V2G Charging station that enables V2G technology y with the standard ISO 15118-20.	ABB	ABB	IPR and ownership defined	8	8	Tools	Operation -focused
V2X management strategies: high-level coordination tool	Decision support tool helping in the identification of the needs of new V2X stations, and the characteristics of these stations (V2X capability, fast-charging, etc.).	GEN-I	-Aggregator (GEN-I) -Technology provider (ABB) -DSO (Elektro Celje) -R&D Centre/University/CoLAB (UL)	IPR and ownership defined	8	8	Tools	Decision-focused
V2X Station	Charging station equipped with Vehicle-to-Everything technology, which enables EV charging and discharging for grid enhancing and local flexibility tasks. It also allows to charge more than one Evs simultaneously. Development of the state-of-the-art V2G Charging station that enables V2G technology with the standard ISO 15118-20.	ABB	-Aggregator (GEN-I) -Technology provider (ABB)	IPR and ownership defined	8	8	Technologies	EV-focused
Visualization of demo site - charging stations	As part of the project, we developed a system for monitoring advanced charging infrastructure at demo locations. The system enables visualization of charging station operations and monitoring of charging/discharging itself.	GEN-I	GEN-I	IPR and ownership defined	7	7	Tools	Decision-focused