

DRIVE2X

D1.4

Detailed characterization of Drive2X use cases

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Executive summary

The Drive2X project develops new expert knowledge, ICT solutions, and hardware technologies to help cope with a mass V2X-based EV deployment future for Europe. It also investigates the role of behavioural uncertainties in V2X and develops policy tools to support sustained V2X roll-out in European smart cities.

Drive2X will implement and test five V2X use cases (UCs) in its lab and demonstration environments. As the table below shows, some UCs are tested in one demonstrator alone, whereas other UCs are tested in more than one demonstrator. The latter is the case with UC1 on medium-term V2B, which is tested in both demo 1 (Isle of Wight) and demo 6 (Amsterdam), and UC4 on V2G integration in distribution networks, which is tested in demo 2 (Isle of Wight), demo 4 (Maia city), and demo 7 (Terni city).

Use case coding	Use case name	Charging scenario
UC1	Medium-term vehicle-to-building charging in commercial buildings for optimized energy operations and grid balancing benefits	Public-access charging station (Building parking lot)
UC2	Long-term vehicle-to-building charging with load aggregation in parking lots for dynamic load balancing and building energy management systems' integration	
UC3	Vehicle-to-home integration with home energy management systems for renewables' integration and tariff optimization in prosumer and consumer homes	Private home charging
UC4	Vehicle-to-grid integration in public charging stations for addressing technical grid constraints	Public-access charging station
UC5	Vehicle-to-grid for network stabilization of locally-managed RES congested grids	Private-access charging station (Facility parking lot)

This deliverable provides a comprehensive characterization of the V2X UCs to be tested in the Drive2X project. The description of the UCs focuses on market and technical requirements. The representation is firstly done visually, with help from the EMSA's business, function, component, information, and communication layers, and secondly, by detailed stepwise IEC 62559-2-inspired listing of primary actor steps in realization of the UC, complemented by respective information exchanging and component use.

The modeling of these use cases adheres to predefined frameworks to ensure compatibility and comparability with other projects, thereby advancing the goal of achieving widespread deployment of e-mobility solutions and particularly, V2X. The goals of the deliverable are:

1. To develop a comprehensive use case characterization methodology relying on both visual and textual elements and based on technical literature and industry-proven methodologies, to ensure interoperability, comparability, and to maximize project impact.
2. To provide a comprehensive market and technical characterization of the V2X UCs' and fork UCs' requirements, aimed at advancing demo implementation of the Drive2X solutions and technologies.

The developed methodology revealed appropriately fitting and detailed, despite the need to continue improving the knowledge on the implementation of the Drive2X UCs.

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Keywords	E-mobility market, Use cases, Architectural framework, Vehicle-to-everything (V2X), Vehicle-to-grid (V2G), Vehicle-to-building (V2B), Vehicle-to-home (V2H)

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Abbreviations and acronyms

Acronym	Explanation
ACK	Acknowledge
API	Application Programming Interface
BEMS	Building Energy Management Systems
DA	Data Acquisition
DBM	Database management
DER	Distributed Energy Resource
DM	Data Management
DP	Data Processing
HEMS	Home Energy Management Systems
UI	User Interface
CPO	Charging Point Operator
DSO	Distribution System Operator
EMSA	E-Mobility Systems Architecture
EMSP	E-Mobility Service Provider
EV	Electrical Vehicle
MGMS	Microgrid Management System
PAYG	Pay as You Go
SGAM	Smart Grid Architecture Model
TOU	Time-of-use
TSO	Transmission System Operator
UC	Use Case
UI	User Interface

UK	United Kingdom
V2B	Vehicle to building
V2G	Vehicle to grid
V2H	Vehicle to home
V2X	Vehicle to everything

1 Introduction

Electric vehicles' (EVs) sales have grown globally across all transport modes across the last decade. By most expert accounts, by 2050, there will be about 1 billion EVs on the road. Europe, which is one of the world's largest EV markets, could potentially make up 30 to 50% of that figure. Furthermore, while this constitutes a much-awaited opportunity for renewable energy expansion, it also poses risks to the power system linked to currently widespread uncontrolled forms of EV charging.

To ensure the integrity of the power system is maintained in presence of growing EV penetrations, advanced forms of smart charging must be widely implemented. One such form of smart charging is bidirectional EV charging. There are various application scenarios for bidirectional EV charging, including “vehicle-to grid” (V2G), “vehicle-to-home” (V2H), and “vehicle-to-building” (V2B). The collective realization of these scenarios in a bidirectional charging environment is known as “vehicle-to-everything”, or simply “V2X”.

1.1 The DriVe2X project

DriVe2X, a recently funded project under the European Union (EU)'s Horizon Europe Research & Innovation programme, aims to tackle the complex and multifaceted challenges laid out above.

The DriVe2X project develops new expert knowledge, ICT solutions, and hardware technologies to help cope with a mass V2X-based EV deployment future for Europe. It also investigates the role of behavioural uncertainties in V2X and develops policy tools to support sustained V2X roll-out in European smart cities.

The main objectives of DriVe2X are:

1. To consolidate the scientific knowledge base and improve **stakeholder awareness** of V2X concepts, strategies, solutions, and technologies.
2. To study and improve the understanding of **behavioural uncertainties** linked to V2X, while acknowledging EV user's perceptions and expectations as critical factors in V2X uptake and upscaling.
3. To implement artificial intelligence techniques that capture the flexible energy potential from smart charging and leverage it in **dynamic local marketplaces** for V2X flexibility.
4. To develop and demonstrate in real-world conditions next-generation, affordable, and user-friendly V2X solutions and **bidirectional charging technologies**.
5. To assess **impacts from mass deployment** of V2X technologies on the distribution grids, the energy markets, and the broader energy systems.
6. To promote V2X open research and market scale-up, by producing policy tools and insights to support complex decision-making related to **V2X roll-out** in European smart cities.

New solutions and technologies developed in DriVe2X are tested in eight demonstration environments, which are spread across five European countries, specifically the Isle of Wight, in the United Kingdom (UK), the city of Maia, in Portugal, the city of Terni, in Italy, the city of Amsterdam, in the Netherlands, and the city of Budapest, in Hungary¹. The demos support the testing of smart charging business models, which relate to

¹ The objectives and planned technical setup of each of the DriVe2X demonstrators are explained with moderate detail in Deliverable D1.3, on “DriVe2X technical architecture and its functionalities”.

the provision of V2X services or strategies by different key actors in various charging scenarios, i.e., public charging stations, building parking lots, and private homes. These business models need to be tailored to each demo's market and regulatory context, given the diverging regulatory environments for e-mobility.

DRiVe2X will implement and test five V2X use cases (UCs) in its laboratory and demonstration environments. These UCs have been refined/adjusted from a preliminary set of six UCs, which had been first proposed by the consortium during grant preparation stage. The main change in the original list is the consolidation of UC1 and UC6 into one single UC – UC1 – now necessarily modified to offer a more general (less demo-oriented) technical scope to the V2X operations. The remainder of the UCs, i.e., UC2, UC3, UC4, and UC5, already provide appropriate scope for testing, thus not requiring any adjustments. As a result, it is the understanding of the DRiVe2X consortium that the updated UC portfolio serves the project well, offering insights over a wide range of V2X operations and e-mobility players.

Table 1 introduces the Drive2X UCs and the respective charging scenarios.

Table 1 - List of DRiVe2X use case cases and corresponding charging scenarios.

Use case coding	Use case name	Charging scenario
UC1	Medium-term vehicle-to-building charging in commercial buildings for optimized energy operations and grid balancing benefits	Public-access charging station (Building parking lot)
UC2	Long-term vehicle-to-building charging with load aggregation in parking lots for dynamic load balancing and building energy management systems' integration	
UC3	Vehicle-to-home integration with home energy management systems for renewables' integration and tariff optimization in prosumer and consumer homes	Private home charging
UC4	Vehicle-to-grid integration in public charging stations for addressing technical grid constraints	Public-access charging station
UC5	Vehicle-to-grid for network stabilization of locally-managed RES congested grids	Private-access charging station (Facility parking lot)

The DRiVe2X UCs are tested in different demonstration environments. Some UCs are tested in one demonstrator alone, whereas other UCs are tested in more than one demonstrator. The latter is the case with UC1 on medium-term V2B, which is tested in both demo 1 (Isle of Wight) and demo 6 (Amsterdam), and UC4 on V2G integration in distribution networks, which is tested in demo 2 (Isle of Wight), demo 4 (Maia city), and demo 7 (Terni city).

In addition to the above, and as it has been discussed earlier, the electric mobility market regulation often diverges between different countries (including within the EU), especially in what concerns the roles played by the various e-mobility market actors. As a result, the different market, regulatory, and technical contexts of each one of the demo environments will create partially deviating use case requirements. For example, the existence of an e-mobility managing entity in Portugal that acts as a market operations supervisory entity has multiple implications on the technical setup and on the business cases that can be established in that demo. Thus, parallel or "fork UCs" have been devised from UCs tested in more than one demo, which are appropriately tailored to each of those demo's market and regulatory contexts.

Table 2 links the DriVe2X UCs and fork UCs with the project demonstrators where these will be tested.

Table 2 - DriVe2X use cases and fork use cases mapped to the project demonstrators.

Use case coding		Corresponding demonstrators
UC1	UC1.1 (fork)	Demo 1 - Isle of Wight (V2B)
	UC1.2 (fork)	Demo 6 - City of Amsterdam (V2B)
UC2		Demo 3 – Porto Airport (V2B)
UC3		Demo 5 - City of Budapest (V2H)
UC4	UC4.1 (fork)	Demo 2 – Isle of Wight (V2G)
	UC4.2 (fork)	Demo 4 – Maia city centre (V2G)
	UC4.3 (fork)	Demo 7 – Terni city centre (V2G)
UC5		Demo 8 – ASM Terni microgrid (V2G)

The above distribution results then in a total of eight UCs/fork UCs, each of which is comprehensively described in this deliverable (as many as project demonstrators).

1.2 Goals and structure of the deliverable

This deliverable provides a comprehensive characterization of the V2X UCs to be tested in the DriVe2X project. The testing of use cases in DriVe2X takes place primarily in the demonstrator environments (WP9), but also with support from simulation in laboratory environment (WP8), where extreme condition scenarios could be tested, and mass deployment could be evaluated at scale.

The description of the UCs focuses on market and technical requirements. The market dimension is efficiently represented by the EMSA framework's business layer, which has been introduced in Deliverable D1.3 (Tikka, et al., 2024). The technical dimension is more extensively represented. First visually, resorting to EMSA's function, component, information, and communication layers, and then by detailed stepwise IEC 62559-2-inspired listing of primary actor steps in realization of the UC, complemented by respective information exchanging and component use. In summary, the functions and information exchanges among actors or components are illustrated with the EMSA model, and then fully disclosed with UC descriptions.

The modeling of these use cases adheres to predefined frameworks to ensure compatibility and comparability with other projects, thereby advancing the goal of achieving widespread deployment of e-mobility solutions and particularly, V2X.

In a nutshell, the goals of this deliverable are:

1. To develop a comprehensive use case characterization methodology relying on both visual and textual elements and based on technical literature and industry-proven methodologies, to ensure interoperability, comparability, and to maximize project impact.
2. To provide a comprehensive market and technical characterization of the V2X UCs' and fork UCs' requirements, aimed at advancing demo implementation of the DriVe2X solutions and technologies.

The writing of this deliverable has been led by LUT and heavily supported by other consortium partners, given the wide range of technical expertise required to complete the UCs. These partners include TNTU, NEW, ENG,

TNO, TEC, ICO, EMOT, ASM, FloW, SFC, AMS, and ANA. The deliverable is part of WP1 on “DriVe2X concept and visions, use cases, and Validation framework”, and Task 1.4 on “Extraction of relevant use cases, use case characterization, and elicitation of use case requirements”. This deliverable is part of the definition activities of the DriVe2X project, complementing Deliverable D1.3 on “DriVe2X technical architecture and its functionalities”, and giving final definition to the V2X use cases.

The deliverable is further structured in the following manner:

- Section 2 introduces the full span of the UC characterization methodology that has been partially adopted and partially developed within the project, based on the SGAM/EMSA methodology and IEC 62559. The section also presents the logic and justification behind these choices.
- Section 3 presents with comprehensive detail each of the UCs and fork UCs of the project, using the market and technical characterization methodology introduced in Section 2. The representation is done visually, with help from the EMSA’s business, function, component, information, and communication layers, and textually, by using a stepwise listing of primary actor steps towards UC realization, which is complemented by respective information exchanges and component use.
- Section 4 summarizes the contents of document and presents the conclusions to the deliverable.

This deliverable is a key contributor to DriVe2X’s milestone MS01, “Definition activities have been concluded and use cases have been characterized”.

2 Use case characterization methodology

The Drive2X project employs use case development methodology very specifically designed to model e-mobility aspects and features of the EV charging bound energy resources. The model E-Mobility System Architecture (EMSA) is derived from the well-established and recognized Smart Grid Architecture Model - SGAM (CEN-CENELEC, 2012). The EMSA is a three-dimensional model that aims to ensure interoperability and facilitate complexity of the highly dynamic smart grid services, applications, and resources. The model simplifies and reveals complex interactions to inhuman observation enabling self-explanatory interpretation and review of the complex use cases. Furthermore, the EMSA focuses on the e-mobility related domains which are in the key role in defining EV charging oriented applications and services. In where, the SGAM does recognize the mobility perspective of a smart grid but fails to provide in detail description of the e-mobility related domains, the EMSA fills the gap in e-mobility sector.

The EMSA model differs in domains in the wider power system end in which energy conversion, energy transfer from/to EV, electric vehicle and EV user premises are used for better description of application details and to provide better balance in domains as majority of the activities are taking place in the proximity of the electric vehicle. Thus, the Drive2X project opts for employing the EMSA model rather than more generic SGAM. The model visualizes relevant business interactions, functions, information flows between entities, communication protocols and media required to fulfill information flow needs, components that enable physical functionality of the use case. Each vertical layer is mapped horizontally on the zones and domains. The zones describe the system level abstraction, whether the entity operates on low process level or in the market zone. The zones are divided into six levels as follows: process, field, station, operation, enterprise, and market. On the second horizontal axis are the domains that describe in which part of the power system each entity, service and application lie on. The EMSA divides domains into two main categories, mobile and immobile. The mobile category consists of EV user premises and EV domains. These domains are used to describe functionalities, services, and entities that are located onboard or in near proximity of the EV or EV user. The immobile category covers energy conversion and energy transfer domains that are the domain where for instance EV charger related entities, services, and application are mapped. Figure 1 shows the comparison between SGAM and EMSA approaches.

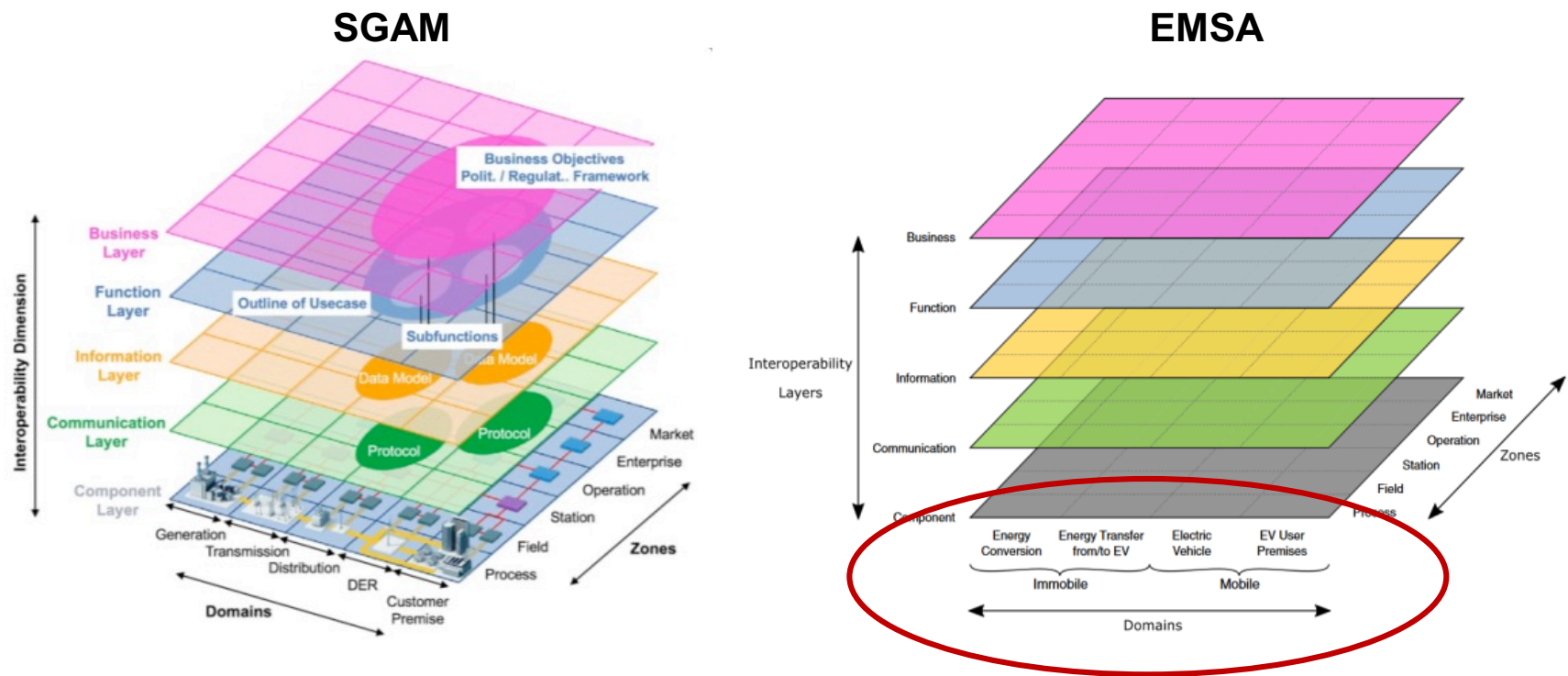


Figure 1. The SGAM architectural model (left) as a basis for the e-mobility-focused EMSA model (right).

This deliverable aims to define functionality of the six unique and complex use cases. As **our goal is to set technical** requirements and general architectural framework, the work absorbs features from the highly visual EMSA model but also standard IEC 62559 approach. Combining the EMSA and the IEC 62559 Use Case Methodology offers a powerful approach for enhancing interoperability and system understanding in the context of smart energy systems. The EMSA provides a structured framework for modeling interactions within the smart energy domain, spanning layers such as components, communication, and information. On the other hand, the IEC 62559 Use Case Methodology focuses on creating and describing use cases, ensuring consistency and clarity in requirements engineering. Integrating best features of these, several benefits emerge:

- **Holistic view:** Combination of these two well established models enable detailed holistic view that encompasses both architecture and requirements engineering. This synergy enhances project's understanding of the system-of-interest.
- **Quality:** The quality of use case descriptions and EMSA models is crucial factor in in describing complex systems. Clear, well-defined use cases and accurate EMSA representations contribute to effective system design and implementation of the project's pilot sites.
- **Interoperability:** Aligning use cases with EMSA ensures consistency across different operating parties and entities. A shared understanding of the system minimizes errors during project's execution and helps to maintain implementation schedule and to manage cost of the implementation.

In summary, integrating features of the EMSA and the IEC 62559 Use Case Methodology fosters a comprehensive approach to designing, implementing, and managing smart energy systems and resources, promoting efficiency and reliability.

The EMSA framework has been partially presented in the Drive2X deliverable D1.3, which showcases and employed the higher abstraction layers of the model. This deliverable focuses on the more technically oriented implementation, thus targeting on EMSA's layers information, communication, and components.

2.1 The EMSA framework

The EMSA model (Kirpes et al., 2019) strategically dissects the e-mobility ecosystem into five synergistic layers, each designed to tackle specific facets of electric mobility systems. This architecture not only simplifies the complexity inherent in e-mobility but also fosters a more organized approach to system development and management. By characterizing the ecosystem into Business, Function, Communication, Information, and Component layers, EMSA facilitates a comprehensive understanding of both the operational and conceptual dimensions of e-mobility. This methodical breakdown ensures stakeholders across the spectrum—from policymakers to engineers—can effectively contribute to and benefit from sustainable electric mobility solutions. The EMSA model's layered approach serves as a framework, guiding the seamless integration of technologies, policies, and market strategies to advance the adoption and efficiency of e-mobility in a coherent and scalable manner.

- **Business Layer:** This layer provides business perspective to reviewing information exchange or market operations between relevant stakeholders within the e-mobility ecosystem. It can contain mapping of regulatory framework and business models as well as economic structures and presentation of relevant stakeholder's business cases, but it also deals with policies, regulations, and market dynamics. From the Drive2X perspective, the business layer is crucial because it defines the overarching goals, stakeholders, and economic considerations. The business layer is also in critical path in abstraction and harmonization of the use cases, while also allowing to differentiate EV users in between cases. The business layer is also highly efficient in framing the business models of the various use cases.

- **Function Layer:** This layer presents use cases, functions, or services within smart grid. It showcases these actions detached from physical actors, applications, or components from an architectural standpoint. For the Drive2X, understanding the function layer is essential as it shapes the operational capabilities and services provided by the grid but also defines what kind of information and communication solutions are needed to functionalities. The properties of the function layer are elaborated in detail in Drive2X deliverable D1.3. The deliverable D1.3 also defines the project's use cases on the function layer.
- **Information Layer:** This layer provides insight of the information flow in smart grid. The information exchange aligns between components and functions. The interfaces for information exchange can be specified. The Drive2X benefits of the information mapping for various reasons, such as it allows explicitly identify information flow that needs to take place between each party or entity. The information flow mapping is in the core of the UC mapping as it defines bare minimum information exchange and data models that is required to realize UCs. Information flows and interactions are in the key in defining the data security aspects, as information layer is the most essential layer in identifying data flows. The data security also sets requirements for the broader cybersecurity framework that ensures utilization of sufficient technological solution to secure data flows. The information layer lies in harmony with the communication layer, that is step towards lowest hierarchical level of the actual components utilized in the UCs.
- **Communication Layer:** In this layer, interoperable information exchange is secured with determination of relevant communication protocols, standards and technology required for functions applied to smart grid. This layer supports Drive2X to frame the technical requirements in detail for each unique UC. The highly technical specification aligns communication solutions with the information exchange requirements set up a step higher layer. The communication layer also facilitates the cyber security aspects by ensuring that technological solution chosen meets the modern cryptography requirements. It is the key in securing interoperable communication link between each party or entity interacting in the UC.
- **Component Layer:** This layer contains physical components such as devices, systems, hardware, or smart grid network infrastructure that are necessary for the functioning of a smart grid. This is the most essential layer to be mapped from the project's implementation perspective. The layer maps each device that is required to enable functionality ensuring communication and information exchange and is the most pragmatic presentation of the actual pilot implementation as it lowers abstraction level all the way to actual physical hardware that each UC requires for operation.

This deliverable picks up where Drive2X deliverable D1.3 stopped, in other words by defining the EMSA model's more detailed layers, information, communication, and component.

2.2 The IEC framework

The IEC use case methodology is the key when complex applications are integrated to the industrial systems mainly already following the IEC standards in many solution, applications and services. The IEC 62559 ensures utilization of the proper terminology, quality guidelines, workflows in the use case definition process. The standard is divided in four parts:

- Part 1: Provides the basis for a common use case management repository, harmonizing use cases.
- Part 2: Defines the use case template.
- Part 3: Specifies the XML import/export format.
- Part 4: Best Practices in Use Case Development for IEC processes and company projects.

Together, these parts facilitate collaboration and organization of use cases. The IEC 62559-2 defines set of basic information of the use case such as, describing name of the UC, description, main actors and of the general remarks. The decryption of the UC is often described as narrative from the primary actors perspective. The same UC can be also describes from the perspective of other involved actors, but in this case the narrative and objectives of the UC may change, as the UC objectives are subject of the primary actor.

The most detailed outlook into US is set up by the UC steps, that describe in detail what actions each actor is taking to fulfill the UC targets. The stepwise description must be implemented in detail such that it succeeds to define information exchanges between actors in detail. This Information exchange follows closely EMSA's information layer, that also visually describes information flows between each actor or device. The stepwise description will be also presented as sequence diagram that shows each actor and information flows triggered by the actions of the actors. Figure 2 shows an example how stepwise table format description can be illustrated as a sequence diagram.

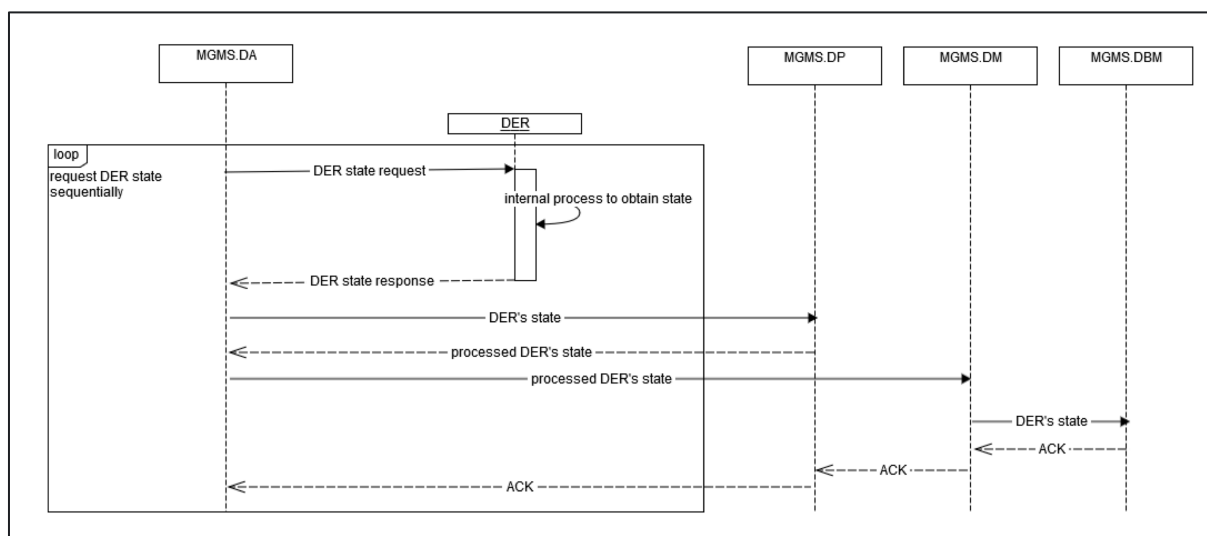


Figure 2. An example of the sequence diagram presentation format in UC development. (Mashlakov, ym., 2019)

2.3 Consolidated Drive2X approach

The Drive2 methodology utilizes EMSA and textual UC definition methods. The EMSA model provides multidimensional visual illustration that not only demystifies the complex applications but helps to identify and elaborate business cases based on the multiple UCs. The EMSA model is a highly structured way of defining stakeholder interaction, but also interaction that takes place between actors and devices. Understanding of the interactions ensures that necessary data and information flows are easy to isolate and study further. The information flow mapping ensures efficient UC implementation and facilitation of the correct technical solutions. The Drive2X also features many aspects of the IEC 62559-2, for instance the basic framing of the UC follows closely IEC's standard approach. The stepwise description of the actor actions

provides further detail on the EMSA modeling, but also ensures that Drive2X UCs are effortlessly available for modeling tools such as UML. The Drive2X UC methodology is summarized in the Figure 3.

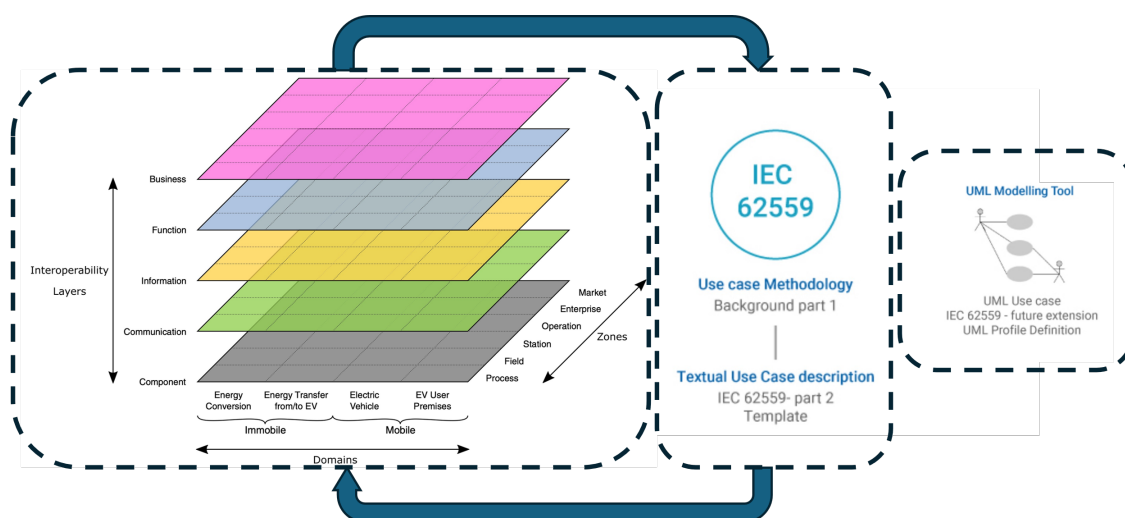


Figure 3. Drive2X use case methodology utilizing well-established industry proven approaches (Adapted from IEC, 2024).

Each UC is described in Section 3 in detail. The definition includes introduction to the UC by employing the EMSA layers starting from the highest abstraction levels, business, and function layers. These layers introduce stakeholders in each UC and map stakeholder interactions. The business interactions differ from the lower abstraction level interaction as the interaction abstraction might be rather high such as contractual interaction, where other layer see interactions as data or information flows via physical communication links.

The UC definition dives into the details with three lower EMSA layers, information, communication, and component. These layers are already framing the UCs in a detailed manner, by mapping information flows and technical solutions required to enable those interactions.

The final part of the UC characterization involves a text-based description, which highlights the primary objectives, the involved actors, and a listing of regulatory and technical prerequisites for UC realization (Table B). Lastly, detailed primary actor steps with specified information exchange and component use are listed (Table C). To ensure harmonization of the approach, each textual stepwise description can be further developed into sequence diagrams or to other UML presentation formats.

Table 3 - General UC framing table template.

Use case coding	Project-based ID of the UC
Use Case name	Formal naming of the UC
E-mobility market actors (Aligned with EMSA Business layer)	Listing of e-mobility market actors involved at broad UC level
Technical actors (Aligned with EMSA Component layer)	Listing of technical component entities involved at broad UC level
Linked demos	Listing of linked project demonstrators at broad UC level
Linked business models	Listing of linked business models at broad UC level

Table 4 - Detailed UC framing table template.

Primary actor	<i>In Drive2X, the primary actor is always the EV user</i>
Goal of primary actor	<i>Specify specific goals of EV user in detailed context of UC or fork</i>
Prerequisites	<i>Specify specific technical and/or regulatory requirements that must or are assumed to be in place to enable the UC</i>
Main UC success scenario (User story, primary actor)	<i>Summary of steps taken to successfully realize the UC</i>
Linked business model	<i>Specifically linked business model (primary actor perspective)</i>

Table 5 - Stepwise depiction of exchanged information and component use for UC realization table template.

Step	Action	Linked information exchange	Linked component's use
1	<i>Specific primary actor step with technical implications</i>	<i>Information messaging incurred by the action</i>	<i>Systems and/or technical components hosting the action</i>
2			
...	...	...	...

3 Characterization of Drive2X use cases

In this section, the Drive2X UCs and fork UCs are comprehensively characterized in their market and technical dimensions by using the consolidated approach introduced in Section 3. Each of these is preceded by an overarching narrative that provides context and purpose to those UCs. A general framing table offers identification details, lists EMSA actor entities, and links up the UCs with the relevant testing/validation environments and business models. The EMSA Market, Function, Component, Information, and Communication layers support the mapping of market interactions and technical elements (high-level functionalities, systems, devices, ICT standards and protocols) of the UC. Lastly, the “main UC success realization” scenario is technically analyzed from the lens of the UC’s primary actor (EV user), with a step-by-step depiction of actions and respective information exchange and component use details being provided.

The e-mobility ecosystem is wide and diversified, including various actors playing different types of market roles, which could even change from country to country. Most actors are present in all Drive2X UCs, whereas others are unique to specific UCs (e.g., the Parking Manager role is only present in UC2). matches the e-mobility market actors from Drive2X with the respective UCs and fork UCs.

Table 6 - E-mobility market actors mapped to the corresponding Drive2X UCs.

Market actor	Description	Linked UCs ²
EV user	An EV user refers to an individual who operates or owns an electric vehicle. EV users can be part of the broader public or belong to a private group, such as a company’s staff, or a car club. The choices and preferences of individual consumers influence the EV market significantly. Their interactions involve purchasing EVs, using charging infrastructure, and participate in V2X services and strategies.	UC1, UC2, UC3, UC4, UC5
Consumer /Prosumer	Customers that interact with EVs include consumers and prosumers of electricity, either in residential (Homeowners or Home Managers) or commercial/industrial environments (Building Managers or Facility Managers). These actors purchase electricity from electric retailers to supply their energy demand. Then, different arrangements are possible for supplying EV charging, including establishing separate supply contracts with EV energy suppliers. In circumstances such as those covered in the Drive2X project, EV users can source electricity directly and at no additional cost from a building or a home’s electric supply. In residential environments, the EV user and the Homeowner/Home Manager are usually (albeit not necessarily always) the same actor.	UC1, UC2, UC3, UC5
Charging Point Operator (CPO)	CPOs establish and manage the infrastructure required for charging EVs. This includes the installation, operation, and maintenance of EV charging stations. CPOs ensure the availability, reliability, and safety of the charging infrastructure, providing essential services to EV owners.	UC1, UC2, UC4, UC5

² The mention of a UC without mentioning any of its fork UCs implies that the market actor is present in all the respective forks.

Market actor	Description	Linked UCs ²
E-Mobility Service Provider (EMSP)	Service providers play a crucial intermediary role in the e-mobility ecosystem. They host the user interface (UI) applications that enable the interactions between the EV users and the charging systems (including smart and bidirectional solutions), as well as with the energy markets. EMSPs also manage transactions and billing services to the appropriate actors, via mobile UIs or local payment systems.	UC1, UC2, UC4, UC5
Distribution And Transmission System/Network Operator (DSO/DNO, TSOs)	Network operators are the entities responsible for developing, operating, and maintaining the electrical grids within specified regulatory conditions and power quality parameters. These grids provide the electricity for EV charging and serve as foundational infrastructure for e-mobility operations. Network operators work together and collaborate with charging infrastructure providers and technology providers to integrate EV charging and ensure grid stability. They are also key recipients/beneficiaries of potential smart charging flexibility services offered in context of ancillary service markets.	UC1, UC2, UC3, UC4, UC5
Electricity Retailer	Electricity retailers sell electricity to customers, which in scope of DriVe2X could be small residential clients or larger building customers, with its own distributed energy resources (DER) (prosumers) or without it (consumers).	UC1, UC2, UC3, UC5
EV Energy Supplier	EV energy suppliers establish contracts with the EV user to provide EV charging electricity according to EV charging-specific electricity tariff structures. Generally, EV users can access energy supply services and pay for them through the intermediary involvement of EMSPs.	UC4
Parking Manager	The parking manager is the actor that handles the parking management system, ensuring equal access to parking space inside a building facility.	UC2
Fleet Manager/operator	The fleet manager or fleet operator is the entity that runs the EV fleet managed by the EV fleet management system, thus dealing with duties such as scheduling, maintenance, and charging/discharging for multiple vehicles.	UC5
E-Mobility Managing Entity (EMME)	The EMME is a supervisory entity that monitors EC charging/discharging sessions and ensures market transparency and equal accessibility to smart charging services by EV users. In the scope of DriVe2X, this role is unique to the Portuguese e-mobility market.	UC2, UC 4.2
Local Energy Manager	The local energy manager runs a local energy system/microgrid, performing microgrid control operations, which include resource allocation for EV charging, PV generation, energy storage, energy use loads, and other loads, under a pre-defined microgrid control logic.	UC5
Market Platform Manager /Flexibility aggregator	This is the entity that manages/runs the local flexibility market platform, which is responsible for leveraging small-scale V2X flexibility into the balancing markets for DSOs. In DriVe2X, this platform accumulates the intermediary role of a flexibility aggregator. In the context of e-mobility, aggregators ensure that EV charging flexibility can be traded as a value-added commodity. In DriVe2X, aggregators are competitive entities considered to be external to the marketplace concept and the project.	UC4.1, UC4.3, UC5
E-Mobility Clearing House Manager	A clearing house is a party that performs financial clearing within the E-mobility market, i.e., transactions' settlement between CPOs and other E-mobility actors ("clearing members") based on contracts established for that effect	UC4.1, UC4.3, UC5

The physical implementation of an e-mobility UC is a result of an amalgamation of high-level (abstracted) technical functions. These functions interact with each other by means of physical and information flows, and when combined form the functional architecture of the UC (Kirpes et al., 2019). The DriVe2X UCs are multifaceted, which results in the consideration of a wide range of e-mobility functionalities. No DriVe2X UC presents a similar functional architecture, and fork UCs present less functional abstraction than the UCs (e.g., different types of energy management strategies between forks UC1.1 and UC1.2). In addition, some of the functionalities are exclusive to some DriVe2X UCs, whereas others have a more uniform distribution.

Table 7 introduces the main e-mobility functions considered in DriVe2X, further matching it with the corresponding UCs and fork UCs.

Table 7 - High-level e-mobility sector functions mapped to the corresponding DriVe2X UCs.

E-mobility function	Description	Linked UCs ³
Metering	The process of accurately measuring energy consumption and production. In all use cases, this includes recording the electricity used by the EV for charging and any energy fed back to the home or grid. Metering captures detailed energy usage data from electric vehicles and charging stations for billing, monitoring, and analysis purposes in V2X systems.	UC1, UC2, UC3, UC4, UC5
Grid management	This involves the coordination of energy distribution and stability of the electrical grid, while integrating EV energy flows via V2G arrangements. For example, grid congestion relief represents the efforts to balance and optimize the power load on the grid to prevent bottlenecks. In other cases, the focus is on absorbing reverse power flows from non-consumed renewable energy. These benefits are deemed “explicit”, since they’re a result from dedicated, compensated grid services requested by the competent grid operator. However, grid management benefits could also be “implicit”, in which case demand response happens strictly from increased V2X flexibility behind-the-meter.	UC1.2, UC4.1, UC4.3, UC5 (explicit) UC1.1, UC2, UC3, UC4.2 (implicit)
EV charging flexibility aggregation	This function pertains to capturing the collective flexible capacity of several EV charging/discharging sessions to enable its consequential participation in DSO balancing services. If this function would not be implemented, marketplace involvement would be deemed infeasible. In DriVe2X, this function is integrated into the local flexibility market platform operations.	UC4.1, UC4.3, UC5
Charging station (CS) management	Charging station (CS) management refers to the operation and maintenance of EV charging stations, ensuring they are functional, accessible, and running efficiently.	UC1, UC2, UC4, UC5
Charging slot management	The allocation and scheduling of charging station time slots to EV users, potentially based on tariffs, user preferences, building energy requirements, and grid requirements.	UC1, UC2, UC4, UC5
Smart EV charging control	Advanced control of EV charging (both ON/OFF control and charging rate adjustments) with purpose of managing the demand on the electricity network caused by EV charging, through implementation of smart charging strategies to spread the load or shift it to off-peak times.	UC1, UC2, UC3, UC4, UC5

³ The mention of a UC without mentioning any of its fork UCs implies that the e-mobility function is present in all the respective forks.

E-mobility function	Description	Linked UCs ³
Home/Building automation	The use of technology, including BEMS and HEMS, to induce automatic control of home and building processes, which in V2H and V2B systems can include integration of EV charging with other home energy systems.	UC1, UC2, UC3, UC5
Energy management	Strategic oversight of energy resources, including EV batteries, to optimize energy consumption and production in V2X models. It involves the control of energy use to improve efficiency and reduce costs. For example, in V2H and V2B environments, this could involve coordinating EV charging with home and building energy production and consumption, as well as stationary battery energy storage systems. In some of the charging stations, a type of energy management strategy is dynamic EV charging load management. This involves controlling the collective charging demands of multiple EVs to optimize energy usage, allowing to distribute energy in an equitable manner or prioritize one or several EV chargers based on occupancy. When choosing to distribute energy in an equitable way, all EVs will charge at the same speed, using the available power resources. In other circumstances, power-based adjustments such as voltage regulation could be performed within charging station boundaries. Thus, energy management can be performed in any of the UC V2X charging scenarios – V2B, V2H, or V2G.	UC1, UC2, UC3, UC4, UC5
EV roaming	EV roaming or “eRoaming” allows EV drivers smart charging of their cars outside their service provider’s network, i.e., across different providers and networks, regions, and even borders, by accessing that charging service provider’s customer account alone. EV roaming delivers to users the true “charge anywhere” experience.	UC4.3
EV management	Overseeing operational aspects of the EV, such as monitoring battery status, scheduling maintenance, and managing charging. User interface for user consultation and input.	UC1, UC2, UC3, UC4, UC5
EV fleet management	The oversight and administration of a group of EVs, which may include scheduling, maintenance, and charging/discharging management for multiple vehicles. The fleet manager needs to ensure the vehicles are fully charged, maintained, and available when needed for either driving or providing V2G services.	UC5
EV user services	Services provided to EV users, which include UI/Applications to access the e-mobility market, navigation, charging station identification and routing, and payment/billing services for smart charging. It enhances user engagement and satisfaction by making the processes of finding charging stations, understanding pricing and billing, managing charging sessions, and keeping track of energy usage more straightforward and user-friendly. Currently, most EMSPs in the market are not prepared to handle charging/discharging events. Thus, this function will require involvement and cooperation from the Drive2X consortium.	UC1, UC2, UC4, UC5
E-mobility data trading	The process of increasing knowledge on the e-mobility market by capturing various types of data to make better informed decisions and optimize performance and user experience of V2X activities. In Drive2X, this is done via implementation of the Electromobility Prediction Interactive Open-Source Tool (EPIOT), which uses machine learning to forecast the load profiles of public urban charging stations, thus improving the load allocation interactions between CPOs and DSOs, and resulting smart charging operations.	UC5

E-mobility function	Description	Linked UCs ³
Parking management	This function links parking space availability with use of the charging stations. It considers user preferences on parking duration and provides guidance to the V2B charging operations. Additionally, it communicates vehicle availability data to the BEMS when possible, verifies duration of parking, and generates invoices based on length of stay.	UC2

The e-mobility sector is evolving at a rapid pace towards harmonization of charging solutions. In the last few years, several new industry standards and protocols for interoperability have been introduced in the ecosystem, which brought new complexities to an already challenging regulatory ecosystem. Furthermore, many CPOs and EMSPs wishing to expand internationally are integrating roaming capabilities into their networks, having to deal with different protocols, regulations, and currencies across various countries. Despite these challenges, standardization will remain a key enabler of mass smart charging deployment.

Table 8 provides a selection of EV charging industry standards and protocols that will support the appropriate implementation of the Drive2X UCs. Most of these, such as OCPP and ISO 15118-20 are transversal to all UCs, whereas others, such as MQTT, will have more limited implementation scope.

Table 8 - E-mobility-related standards and protocols mapped to the corresponding Drive2X UCs.

E-mobility-related standards and protocols	Description	Linked UCs ⁴
Open Charge Point Protocol (OCPP)	OCPP is a communication standard for the interface between electric vehicle charging stations and a central management system. It allows for the control and monitoring of charging stations, supporting various functions such as remote start/stop of charging, data transfer, and firmware updates.	UC1, UC2, UC3, UC4, UC5
Open Charge Point Interface (OCPI)	OCPI is an open international protocol that enables EMSPs, CPOs, and energy management service providers to securely exchange data for electric vehicle charging services. It provides accurate and standardized charging station data, including location, accessibility, pricing, real-time billing, and mobile access to charge stations.	UC4.1, UC4.2
IEC/ISO 15118-20	ISO 15118-20 is a communication protocol that defines the interactions between electric vehicles and the charging stations. It includes provisions for secure communications, plug and charge capabilities, and bidirectional power flows.	UC1, UC2, UC3, UC4, UC5
Open Automated Demand Response (OpenADR)	OpenADR is designed for demand-side management, enabling customers to respond to price changes and grid reliability signals. This protocol supports smart grid operations, providing for automated demand response actions on the end-use customers' end.	UC1, UC2, UC3, UC4, UC5
Open Smart Charging Protocol (OSCP)	OSCP is an open protocol used for communications between charging point management systems and energy management systems of site owners or DSOs. It facilitates capacity-based smart charging of EVs by enabling real-time prediction of the local	UC1.1, UC1.2

⁴ The mention of a UC without mentioning any of its fork UCs implies that the standard/protocol is present in all the respective forks.

E-mobility-related standards and protocols	Description	Linked UCs ⁴
	electricity grid capacity, to be communicated by means of 24-hour forecasts to the CPOs.	
IEC 62196-3	IEC 62196-3 is a standard that specifies the configuration of the vehicle connector and the charging station connector (the "plug") for DC charging. It defines the physical interface and communication protocol to ensure compatibility and safety in DC fast charging.	UC1, UC2, UC3, UC4, UC5
Representational State Transfer (REST) API	Representational State Transfer (REST) API is a set of web services that operate over HTTP protocols. REST APIs enable applications to communicate and exchange data over the internet in a simplified and stateless manner, often used for web services.	UC1, UC2, UC3, UC4, UC5
Message Queuing Telemetry Transport (MQTT)	MQTT is a lightweight messaging protocol that uses TCP/IP for the exchange of messages between devices. It is designed for connections with remote locations where a small code footprint is required and/or network bandwidth is at a premium.	UC5, UC4.3

The following subsections elaborate further on the e-mobility market actors, technical functionalities, and industry standards and protocols considered for each Drive2X UCs or fork UC.

3.1 UC1 Medium-term vehicle-to-building charging in commercial buildings for optimized energy operations and grid balancing benefits

This UC feeds prospects of a future where EVs parked at commercial buildings serve not only as mobility enablers but also as elements in creating a smarter, more sustainable energy grid. This is possible through implementation of medium-term V2B, which could be approximately defined as smart charging operations of duration under 12h. This strategy transforms parked EVs into active participants in building energy, potentially offering benefits to both commercial enterprises and EV owners. For commercial businesses, the adoption of V2B systems enables them to optimize energy tariffs by employing smart charging strategies within their parking lots. By timing the charging and discharging of EVs in alignment with peak and off-peak electricity rates, businesses can achieve considerable savings on operational costs. Furthermore, this approach enhances their sustainability efforts by reducing dependence on conventional energy sources and incorporating renewable energy stored in EVs. EV owners stand to gain from this setup as well. By allowing their idle vehicles' batteries to be controlled by a building manager, they can generate additional revenues that help offset the (still high) costs of acquiring an EV.

This UC is tested and validated in two project demonstrators, the Isle of Wight, and the City of Amsterdam. Each of these demos has own nuances because of the differences in the regulatory and e-mobility market frameworks, and in the technical setups of the demo sites. The diverse testing environments create a good foundation for complementary testing and validation, while also helping to understand gaps in regulation, standardization, and harmonization. Table 9 depicts the general framing for UC1.

Table 9 - General framing for UC1 Medium-term vehicle-to-building charging in commercial buildings for optimized energy operations and grid balancing benefits.

Use case coding	UC1
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Use Case name	Medium-term V2B charging in commercial buildings for energy optimization and grid balancing benefits
E-mobility market actors (Aligned with EMSA Business layer)	Building/Facility Manager, EV User, CPO, DSO/DNO, TSO, EMSP, Energy Markets, which may include various entities, such as Electricity retailers
Technical actors (Aligned with EMSA Component layer)	EVSE Controller, CS Controller, CS EMS, CS Management system, CS Operator system, EV Charging controller, Battery Management System, BEMS, Smart Charging session Webapp, AD-hoc UI, Grid Management system)
Linked demos	• Demo 1 - Isle of Wight (V2B) • Demo 6 - City of Amsterdam (V2B)
Linked business models	• BM2 - Flexibility services offered by EV owners to building managers (EV user's perspective) • BM4 - Building tariff optimization leveraged by parking lot smart charging (Building Manager's perspective) • Flexibility services offered by building/facility managers to DSOs (Building Manager's perspective) • Distribution network management through procurement of local V2X flexibility

3.1.1 UC1.1 Isle of Wight V2B testing and validation environment

In the V2B demo site of the Isle of Wight, the Drive2X project will engage tourism accommodation units and possibly other types of similarly small commercial facilities to test the potential of bidirectional EV charging to enhance building energy management operations, while promoting corporate sustainability and innovation, and the general island's tourism scene. In this synergistic approach, EV users, building managers, and a variety of E-mobility technology partners come together to optimize energy usage locally, while potentially offering enhanced services that support the management of the islands' distribution network.

The demo will install five of the Drive2X 20 kW bidirectional EV chargers in parking lots of 2-3 small buildings in the island. Some of these facilities will feature in-house DER, such as thermal storage, PV power production, heat pumps, or battery electric storage, in which case the energy management of the facility will not only be integrated with the chargers but also with these units. For diversity of testing scenarios, some of the buildings will not be equipped with DER. The differential operational outcomes between the two types of environments will provide valuable lessons to the demonstrator's synthesis of results.

The facilities will be served by TOU retail electricity tariffs, and the use of the EV battery storage capacity of the EVs will be leveraged together with or without the DER to meet the energy demand more efficiently and with lowered tariff costs. Ideally, with optimized energy management, the buildings will be able to support the distribution grid through demand response events. This could take shape of an explicit service provision to the DSO via a flexibility marketplace, or a mere implicit contribution through energy demand behavioural change. Either case is supportive of the Isle of Wight's distribution network's management, particularly allowing for further renewable energy integration into the grid.

In this demo, two types of EV users will be recruited. The first type are tourists who lease a bidirectional charging-compatible EV, whereas the second type are commercial building EV fleet staff users. The latter may also be leased to the management of the facility. V2X-compatible EVs are being leased by Drive2X partner Future Isle of Wight from an EV manufacturer for the purpose of the demonstrator.

Charging station intelligence solutions will be provided to the demo by the Drive2X consortium together with the bidirectional EV chargers. Examples of this are software solutions for integration of DER assets, or the smart charging algorithms that optimize charging control based on EV user input and energy management objectives. In spite of this, the demo will have to partner with some local stakeholders. The DSO (DNO in the UK) will support the link of the demo with the distribution network management and ensure that grid benefits can be ascertained from the building energy management optimization. The electricity retailer will provide the building with appropriate TOU tariffs that incentivize energy efficiency and internal DER operations. The management of the charging stations and operation and maintenance of the EV chargers are functions that will optimally be provided behind-the-meter with support from both building management and Drive2X project's expertise. Regardless of this, the need for partnering with a CPO is still being studied and will depend on how electric mobility regulation frames the implementation of the demonstrator. EMSP services are also planned to be provided internally through implementation of a Drive2X-specific UI launched locally and with the ability to trigger bidirectional EV charging/discharging sessions via some web application. Traditionally, an EMSP would also manage financial transactions and billing for the service of supplying charging electricity. However, in the case of these behind-the-meter operations, the EV charging electricity is expected to come from the building clients, which makes involving EV energy suppliers unnecessary. In addition, EV user compensation for the energy management services provided to the building manager needs to be ensured. The exact shape this compensation will assume is also still under discussion. It is possible, for example, that instead of direct monetary compensation the building manager offers EV users specific incentives, such as discounted hotel services, in exchange for the ability to access their battery capacity for building management purposes.

The Isle of Wight V2B demo will showcase a sustainable energy management strategy that integrates electric mobility into the building's energy system and the power grid, while benefiting the local economy.

3.1.1.1 Mapping of market and technical requirements

For a successful V2B implementation, the system would need to align with market trends, offer clear economic benefits to encourage user participation, and comply with energy market regulations. It would involve assessing the potential for revenue generation or cost savings through smart energy management, exploring incentives for participation, and ensuring the V2B system is equipped to respond to market signals.

In the context of EMSA, as shown in Figure 4, the business layer provides a strategic framework for identifying the market requirements of a medium-term V2B use case. Within this use case, a synergistic approach is employed where electric vehicles (EVs) serve as active assets in commercial building energy management, contributing to both operational efficiency and corporate sustainability. Key market players include commercial facilities seeking to leverage V2B technology to enhance energy management and reduce reliance on traditional energy sources. They aim to utilize the stored energy in EVs to lower energy tariffs and balance consumption, especially during peak demand periods.

EV users, for example tourists and commercial fleet operators, are integral to the V2B ecosystem. Their participation is driven by user-centric platforms that allow them to manage charging sessions and receive incentives for energy contribution. The usability and economic benefits provided through these platforms are for user engagement and the overall success of the V2B use case. Energy retailers and DSOs are responsible for offering dynamic TOU tariffs and ensuring that the V2B system's integration into the grid yields benefits such as enhanced renewable energy use and grid stability. These entities work closely with E-mobility technology partners who supply the necessary hardware and software for intelligent charging and energy management. From a regulatory standpoint, the use case must navigate the electric mobility regulations, which influence the roles of CPOs and the structure of EV user compensation. The economic model must be flexible to accommodate various forms of compensation, whether direct monetary incentives or indirect benefits like discounted services.

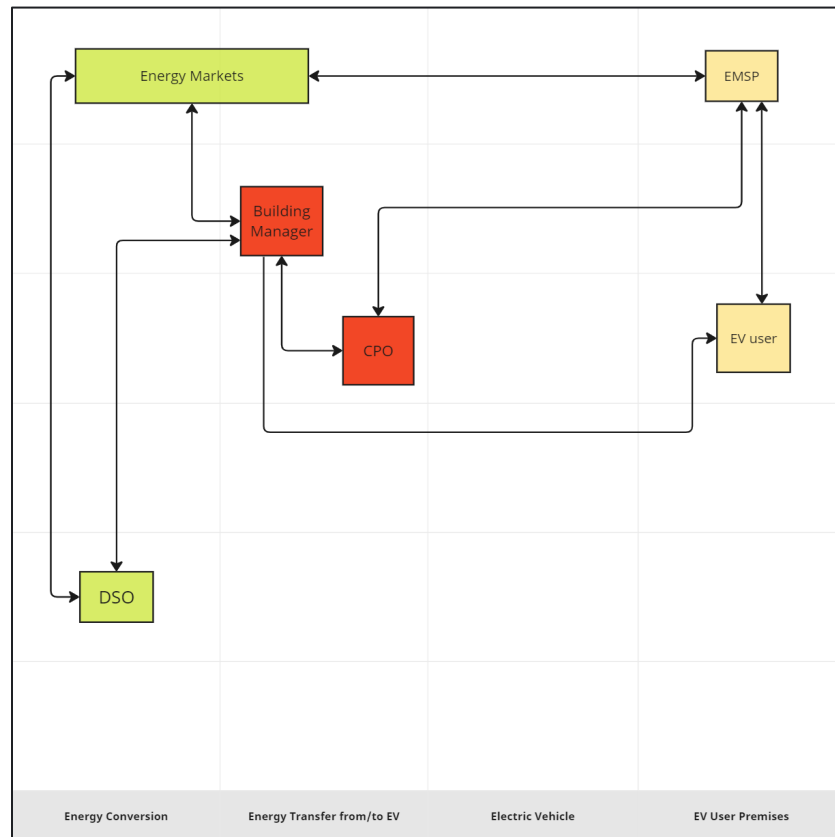


Figure 4 - EMSA Business layer for fork UC1.1 - Isle of Wight testing and validation.

The function layer of Use Case 1.1 – Isle of Wight testing and validation, as depicted in the Figure 5, represents the various functionalities that are part of an integrated EV ecosystem. The functions are categorized across different levels, reflecting the range of operations from ground-level processes to market interactions. The function layer for this use case – Isle of Wight testing and validation includes, Charging Slot Management, Building Automation, Grid Management (implicit), Metering, Smart EV Charging Control, EV Management, EV User Services. These functions collectively enable a robust and user-friendly EV ecosystem that can support the UC's objectives.

As shown in Figure 6, the EMSA Component layer for UC1.1 – Isle of Wight testing and validation illustrates the technical aspects of an integrated EV charging ecosystem, outlining the key components and their interactions. The diagram organizes these components into different zones and domains that reflect their role.

At the top level, the Energy Market System interfaces with the Grid Management System, indicating a connection between energy trading platforms and grid operational controls. The CS Operator System encompasses the BEMS and CS EMS, which manage energy within buildings and charging stations respectively. The CS Controller links to the EVSE (Electric Vehicle Supply Equipment) Controller, suggesting a direct control line for charging hardware. Within the field level, the EV Systems include an EV Charging Controller and a Battery Management System, which work in tandem with various Sensors and Controllers. These components are fundamental for real-time monitoring and management of the EV charging process and battery health. An Ad hoc UI is also depicted, hinting at a user-facing platform that could allow EV users to interact with the system, for functions like scheduling and monitoring charging sessions.

The interconnections between these components suggest a complex network where data and control commands are exchanged to optimize energy usage in a medium term, provide user services, and manage the charging and discharging of EV batteries, covering V2B interactions.

In the EMSA Information Layer for UC1.1 – Isle of Wight testing and validation, the focus is on establishing the standards and protocols for information exchange within the EV charging infrastructure.

Communication protocols and standards work in unison to ensure seamless operation and interaction between various system components. The Open Charge Point Protocol (OCPP) is for the control and monitoring of bi-directional charging sessions. Alongside, the IEC 61850 standard plays a role in substation automation and orchestrates communication between grid management systems and measurement devices, ensuring interoperability across diverse electrical equipment. To facilitate user interactions with the V2B system, REST APIs are employed, enabling users to schedule charging or discharging sessions tailored to individual preferences or grid requirements. The hardware aspect of safe and compatible connections for energy transfer is addressed by the IEC 62196-3 standard, which covers the connectors used in V2B charging.

Further enhancing the communication between the EV and the building's energy management systems, the IEC/ISO 15118-20 standard automates and optimizes the charging and discharging processes. For demand-side energy management, protocols like OpenADR and OSGP are instrumental in automating the energy demand to leverage the EV's stored energy efficiently, especially during peak demand times.

These protocols are supported by a robust Communication Layer, as shown in Figure 8, that includes technologies such as TCP/UDP for reliable and quick data transmission, respectively. TCP is used where data integrity is crucial, while UDP is applied in scenarios where speed is preferred over reliability. Serial communication remains a reliable choice for direct device-to-device data exchange. For secure and real-time data interactions, web services like HTTPS and WebSocket are critical, ensuring that users can securely monitor and manage energy flows and control charging sessions in real time. These combined technologies form the backbone of the V2B communication infrastructure, facilitating a smart, responsive, and user-friendly ecosystem. Together, these information and communication layers create a cohesive framework that allows for the sophisticated interaction between EVs and buildings, enabling not just energy consumption but also the provision of energy back to the building.

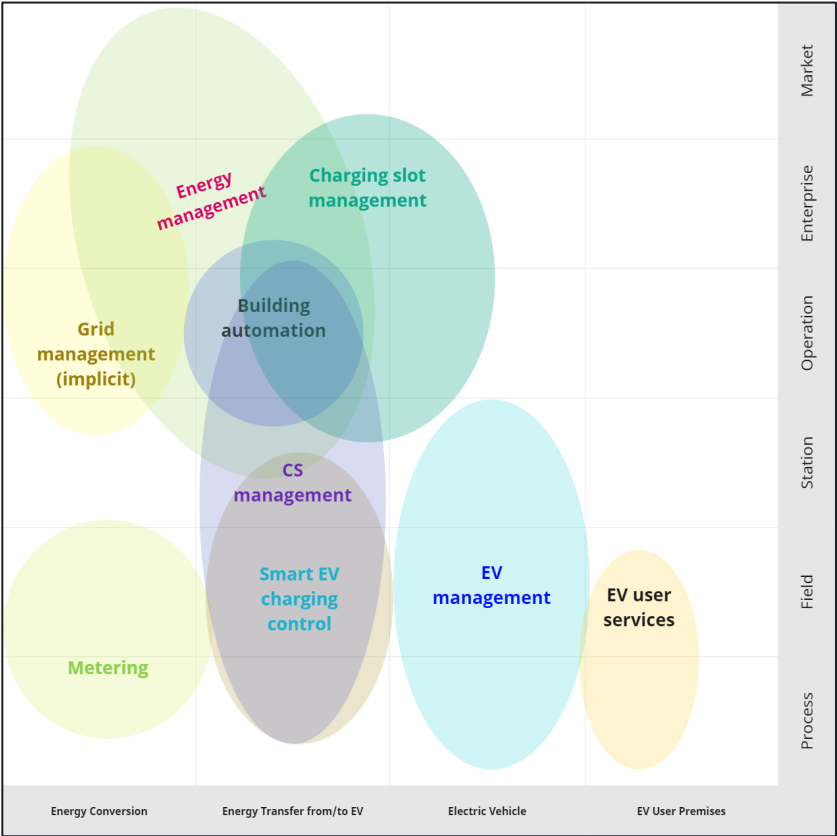


Figure 5 - EMSA Function layer for fork UC1.1 - Isle of Wight testing and validation.

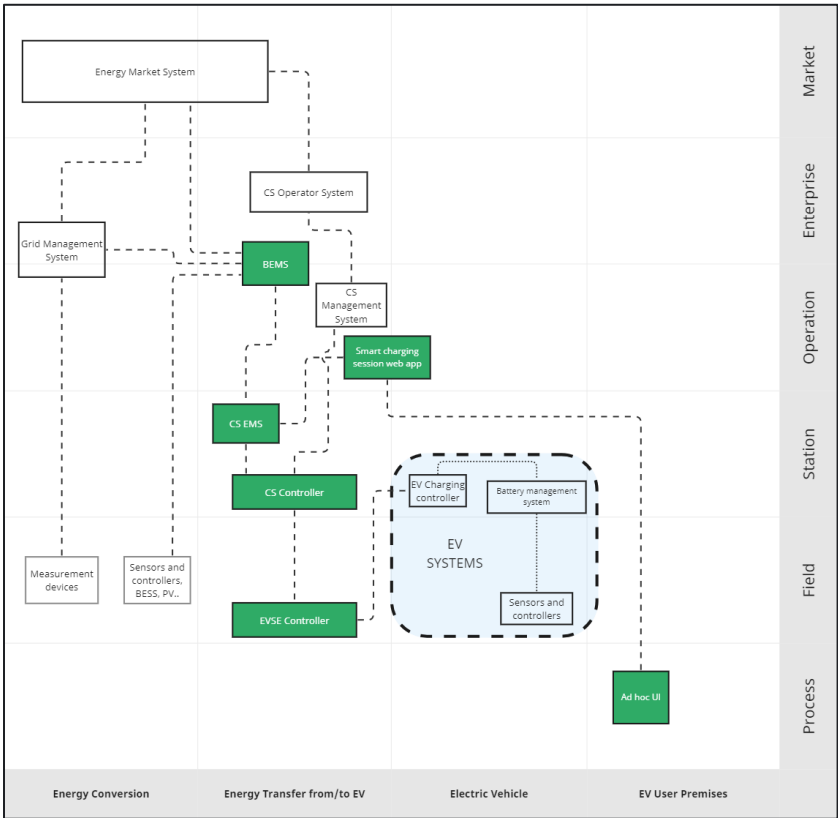


Figure 6 - EMSA Component layer for fork UC1.1 - Isle of Wight testing and validation.

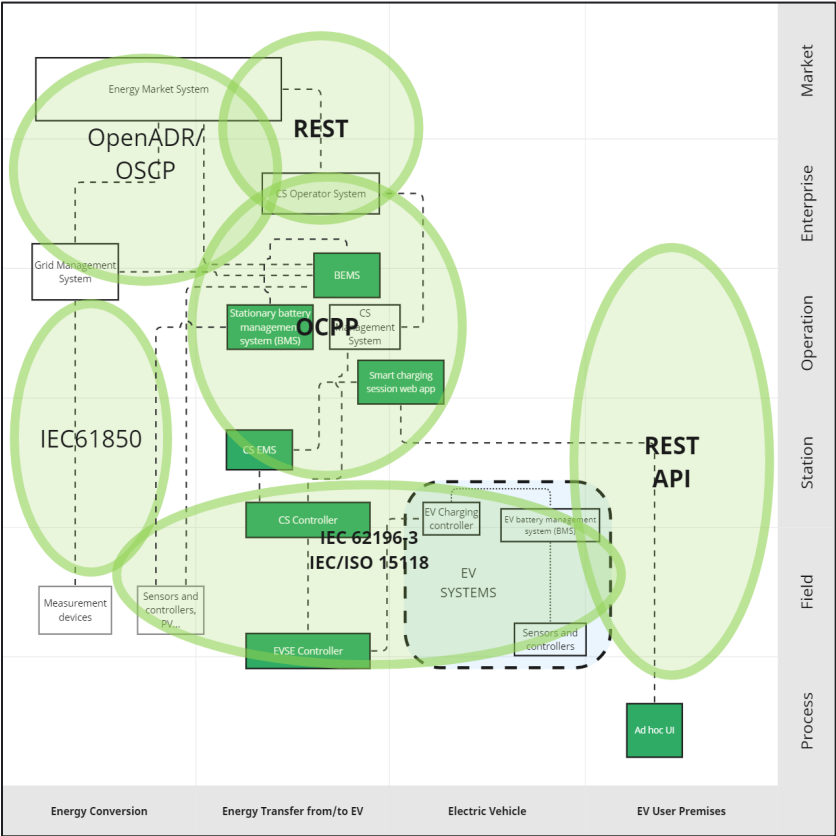


Figure 7 - EMSA Information layer for fork UC1.1 - Isle of Wight testing and validation.

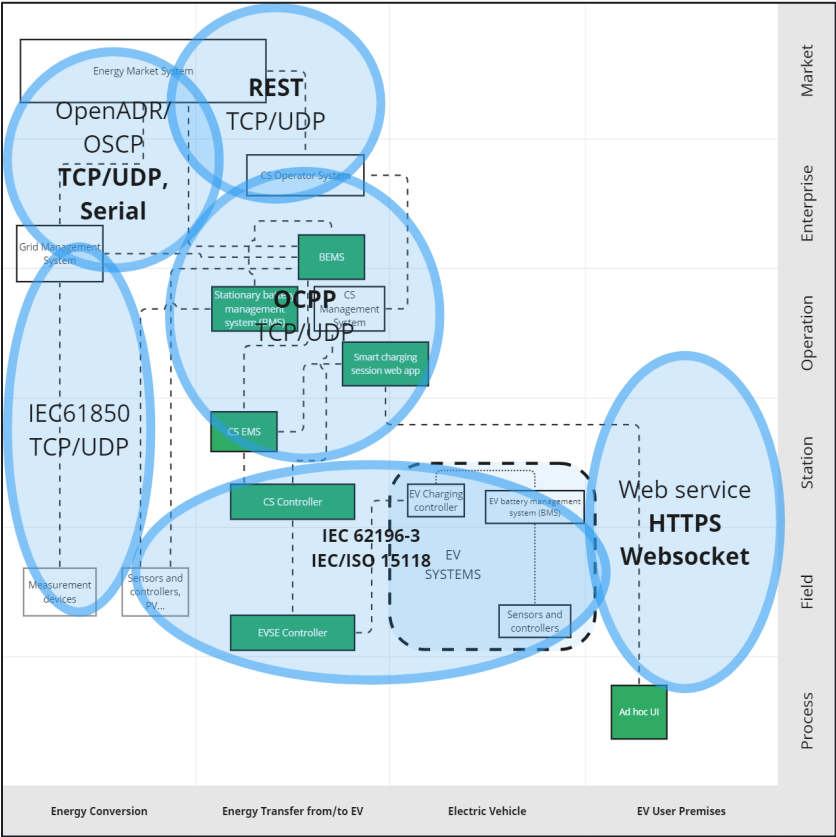


Figure 8 - EMSA Communication layer for fork UC1.1 - Isle of Wight testing and validation.

3.1.1.2 Integrated characterization of requirements

A use case is a powerful tool that allows us to understand how users interact with a system or product. It provides a structured way to describe in detail how systems and devices interact and what is user's role in the UC. The following detailed description summarizes the core element of the fork UC1.1 in Table 10. The fork UC1.1 is further developed into stepwise depiction of exchanged information and component use for realization in Table 11. In essence, this depiction captures the conversation between different component involved in the UC.

Table 10 - Detailed framing for fork UC1.1 - Isle of Wight testing and validation.

Primary actor	EV User
Goals of primary actor	1. Charging of EV, with designated SOC at disconnection time to ensure mobility needs. 2. Offset EV upfront costs by capturing additional value streams from V2B strategies.
Prerequisites	• BEMS availability and possibility of integration • Presence of relevant DER, e.g., PV, electric heating • EV/Charging port and charger protocol compatibility • Technical integration of bidirectionality • Regulatory support to testing and validation activities
Main UC success scenario (User story, primary actor)	Isle of Wight visitor Martha leases an EV from a local car club and checks-in at a hotel in the early morning. Arriving at the parking lot, she plugs the vehicle into a charger. She uses an ad-hoc user interface to trigger a bidirectional charging event. During the smart charging event, the vehicles' s battery is equated to a distributed resource at the service of the BEMS, being managed together with other assets such as stationary storage or renewable energy, contributing to the building's energy balance. Later in the morning, Martha decides to do some sightseeing, terminating the charging event. Because Martha had originally pre-defined a minimum level of SoC at disconnection, the EV has about 80% SoC at that time. Martha drives off from the hotel expecting a stress-free day.
Linked business model (Primary actor's perspective)	BM2 - Flexibility services offered by EV owners to building managers BM4 - Building tariff optimization leveraged by parking lot smart charging Flexibility services offered by building/facility managers to DSOs Distribution network management through procurement of local V2X flexibility

Table 11 - Stepwise depiction of exchanged information and component use for UC1.1's realization.

Step	Action	Linked information exchange	Linked components' use
1	EV driver arrives to the parking lot	N.A.	N.A.

Step	Action	Linked information exchange	Linked components' use
2	EV driver plugs car into the bidirectional charger, beginning charging event	ISO 15118-20 information of the plug-in event	EV charging controller, EVSE controller
3	EV driver interacts with Ad-hoc UI	Smart charging session creation	Ad-hoc UI, Smart charging session WebApp
3.1	For enrolment with Drive2X, EV driver accepts GDPR and registers user account (if not done earlier)	Acceptance of GDPR and registration	Smart charging session WebApp
4	EV driver inputs smart charging session information	Input of estimated departure time and minimum SOC preference at that time	Ad-hoc UI, Smart Charging Session WebApp
5	EV driver confirms all the inputs, which sends signal to initiate charging session	Start of charging command	Ad-hoc UI, Smart Charging Session WebApp
6	Smart Charging WebApp backend initiates charging session and relays information to CS EMS	Initiation of charging session, relay of user input data	Smart charging session WebApp, CS EMS
7	CS EMS records charging session in scheduling application and sends charging event start signal to CS controller	Charging session scheduling, start signal	CS EMS, CS Controller
8	CS controller relays signal to EVSE controller, which starts charging session according to ISO15118-20 and subscribes to real-time data streams from the vehicle's charging controller and BMS	Relay of start charging signal, subscription to vehicle data streams	CS Controller, EVSE Controller, EV Charging controller, EV BMS
9	CS controller sends session information upstream and starts relaying OCPP messaging on charging event	Session information sent upstream, continual OCPP messaging	CS Controller, CS EMS, CS Management System, CS Operator System, Energy Market System
10	CS EMS sends charging session information to building EMS, which initiates optimization of charging session within the boundary conditions to meet building's energy balance targets	Sends session info to BEMS for energy management optimization	CS EMS, BEMS
10.1	BEMS interacts with the energy markets and DSO to acquire data that supports optimization goals	Messaging between BEMS, Energy markets and DSO using OpenADR, OSCP	BEMS, Grid Management System (DSO), Energy market System
11	EV driver interacts with vehicle's UI or Ad-hoc UI, terminating charging session	Charging session termination message	Ad-hoc UI, Smart charging session WebApp, EV Charging controller

Step	Action	Linked information exchange	Linked components' use
12	The web application backend sends remote session end signal to CS EMS	Session end signal sent	Smart charging session WebApp, CS EMS
13	CS EMS terminates charging session and sends termination signal to CS controller	Session end signal sent	CS EMS, CS controller
14	CS controller sends charging session terminations signal to EVSE controller, which terminates EV smart charging session and results in unlatching of the charging port (locking mechanism)	Event termination signal sent	CS Controller, EVSE controller
15	CS controller sends signal upstream that charging session is terminated	The session has ended	CS controller, CS EMS
16	CM EMS sends session statistics to Smart charging session WebApp server, which compiles charging statistics report for Ad-hoc UI	Receives session status	CS EMS, Smart Charging Session Web App, Ad-hoc UI
17	EV driver is offered possibility of seeing event statistics in UI, and is informed of billing (if applicable), after which vehicle is unplugged	Displaying of charging statistics and billing information to user (by user discretion)	Smart Charging Session WebApp, Ad-hoc UI
18	EV driver leaves the parking area.	N.A.	N.A.

3.1.2 UC1.2 Amsterdam V2B testing and validation environment

The Amsterdam demonstrator will test the integration of V2B strategies in building environments with high DER penetration. The venue is the Amsterdam multi-sport Arena, located in an area that is nation's centre for sport, music, and leisure events, welcoming over 100 000 visitors in busy evenings, and generating high volume car traffic. The demonstration aims to investigate the role active commercial customers such as the Arena, equipped with flexible DER assets including V2X, could play in relieving local distribution congestion challenges faced by the DSO.

The demo will deploy thirteen 20kW three-phase bidirectional chargers in a parking lot location of the Amsterdam Arena. The Arena is powered with rooftop PV and has recently installed a 3MW/2.8MWh battery system, already performing sophisticated internal load management and self-consumption, as well as providing grid stabilization services to the DSO. The demonstration will thus strive to understand how V2B at scale could further enhance these operations. Various recruitment features are still being discussed, but EV users accessing the V2B services will belong both to the general public (to cover for weekend, events-linked, evening-time use) and the Arena's staff (to cover for weekday regular work hours' use).

One of the interesting nuances of the Amsterdam demo pertains to the potential dynamic load management of the charging facility in context of energy management of the Arena, more specifically in conjunction with its large battery and PV systems. While in commercial built environments, energy management often falls under the auspices of a building manager (here represented by the Arena), in this case (at least) the battery management system is being controlled by a third-party entity. It is planned that the Drive2X consortium will partner with this entity with view to ensure smooth integration of the project's solutions with that system. Drive2X is expected to provide charging station load optimization solutions, and if possible, the Arena to be established as a non-commercial "charging station holder", which is equated to the CPO role. Electricity for EV charging will ideally come from the building's electricity supply contract, at reduced or no cost for the EV user as an incentive to the recruitment. Regulation allowing, the EMSP role will be centralized within the

project with a web application that will be able to initiate and monitor the bidirectional charging sessions. Currently, there is no visibility over what type of compensation could EV users obtain from the energy management services provided to the Arena (i.e., monetary benefits, in-kind contributions...). If tangible monetary benefits are negotiated, then transactional and billing features for both charging and discharging activities will have to be integrated in the UI.

3.1.2.1 Mapping of market and technical requirements

To establish a successful V2B implementation in Amsterdam, akin to the Isle of Wight example, we would anticipate a system that is attuned to the unique market dynamics of the city, while also being adaptable to regulatory frameworks and technological advancements. As shown in Fig. 6, the EMSA business layer in Amsterdam focuses on integrating electric vehicles into the energy management of high-traffic commercial venues like the multi-sport Arena, which faces significant energy demands during peak event times.

Commercial entities such as the Amsterdam Arena are at the forefront of adopting V2B systems, not only to handle their substantial energy requirements but also to play an active role in stabilizing the local grid. This integration of energy management and grid support exemplifies a strategic move towards energy transition within the commercial sector.

EV users are central to the V2B ecosystem, with a range of participants from the general public attending events to staff fleet operators. These users would be supported by user-friendly platforms enabling them to conveniently manage their charging preferences. Incentives for participation, such as reduced or complimentary charging, would be key to encouraging widespread user engagement.

The Transmission System Operator (TSO) would be instrumental in managing the high-level energy exchanges stemming from V2B activities, ensuring a balanced and efficient energy grid. Meanwhile, DSO handles the localized distribution challenges, optimizing the use of energy contributions from V2B systems to alleviate congestion.

CPOs and energy retailers jointly provide the necessary infrastructure and dynamic tariff models to make V2B operationally viable and economically attractive. This would involve a careful orchestration of infrastructure management and energy pricing to ensure the economic feasibility of the V2B system.

Regulatory frameworks would shape the operational scope of commercial entities like the Amsterdam Arena, influencing how they interact with the energy system and compensating EV users. The economic model would need to be versatile, capable of accommodating various compensation structures to meet the needs and preferences of all stakeholders involved.

This V2B use case in Amsterdam, framed within the EMSA business layer, maps out the market requirements for a medium-term implementation, highlighting the potential for EVs as active participants in energy management. It would underscore the collaborative efforts required between commercial facilities, EV users, TSOs, DSOs, CPOs, and energy retailers to create a sustainable, economically beneficial V2B ecosystem.

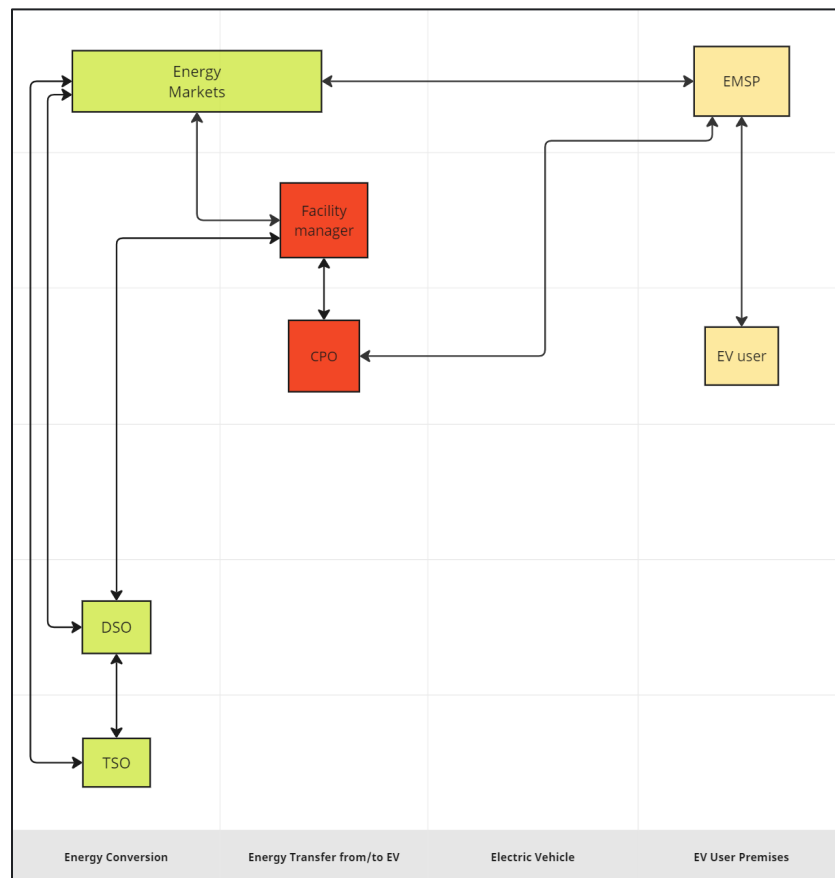


Figure 9- EMSA Business layer for fork UC1.2 - Amsterdam testing and validation.

The EMSA Function layer for UC1.2 — Amsterdam testing and validation includes key operational functions similar to UC1.1, with a specific focus on grid management congestion relief. This function is to the UC1.2, addressing the unique energy demands and management needs of high-traffic commercial venues like sports arenas. It complements other functions such as metering, energy management, charging slot management, and EV user services, which collectively facilitate the efficient integration of EVs into the building's energy system and support dynamic energy balancing within the grid.

As depicted in Figure 11, the EMSA Component layer for UC1.2 – Amsterdam testing and validation outlines the architecture of an integrated EV charging system. The diagram organizes the components into several layers and domains, illustrating their interconnectivity and the flow of information and control commands within the system.

At the market level, we have the Energy Market System, which interacts with the Grid Management System. This indicates the integration of energy trading and grid operations, ensuring that the electricity used for EV charging is managed within the broader context of energy demand and supply on the grid. Descending to the enterprise level, the CS Operator System is connected with the BEMS and the CS Management System. The BEMS likely monitors and controls energy use within buildings, including the potential to manage stationary battery storage. The CS EMS is responsible for the operational aspects of EV charging stations, including the smart charging session web app. The CS EMS is connected to a Smart charging session web app, which facilitates interactive management of charging sessions for users and integrates with the Ad hoc UI.

The operation level showcases the CS EMS, which aggregate data and manage energy at the charging stations. It connects to the CS Controller, a pivotal component that orchestrates the charging processes and communicates with the EVSE Controller, which in turn controls the actual charging equipment. Within the station level, the EV Systems are highlighted. This includes the EV Charging Controller, which manages the delivery of power to the vehicle, and the BMS, which monitors and manages the battery's health, charge levels, and temperature, ensuring safety and efficiency. These systems are supported by various Sensors and Controllers, providing real-time data for optimal operation.

The field level includes the Ad hoc UI, which represents a user interface for EV users. This interface is for allowing users to interact directly with the system, offering functionalities such as starting or stopping a charge, scheduling charging times, and even viewing the status of the charge or battery health. The diagram suggests a network where data and control commands are exchanged to optimize energy usage, provide user services, and manage the charging and discharging of EV batteries, including V2B interactions.

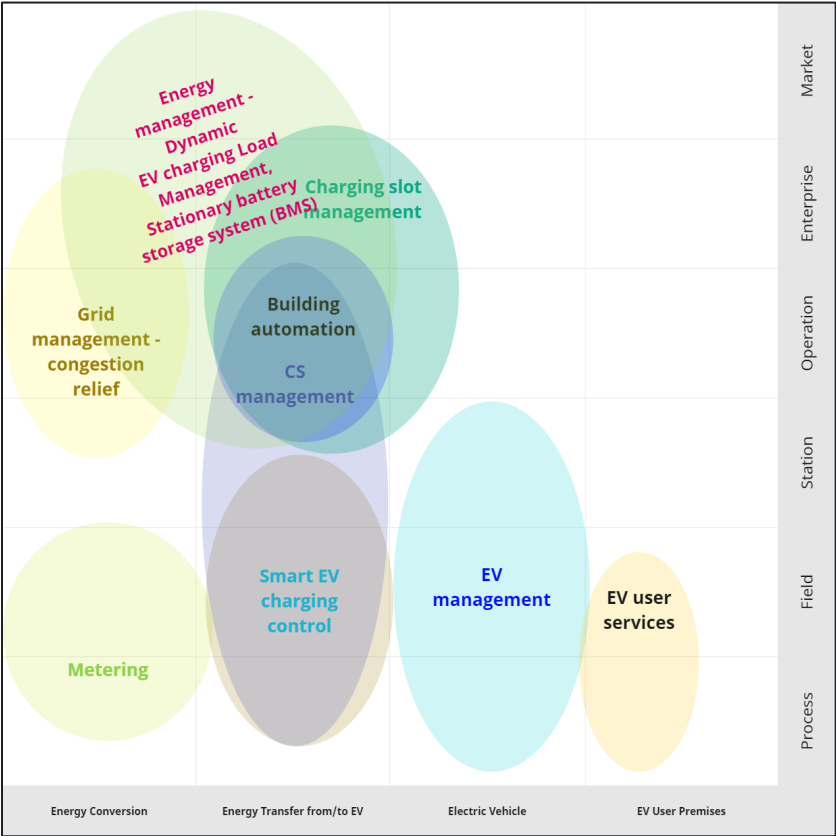


Figure 10 - EMSA Function layer for fork UC1.2 - Amsterdam testing and validation.

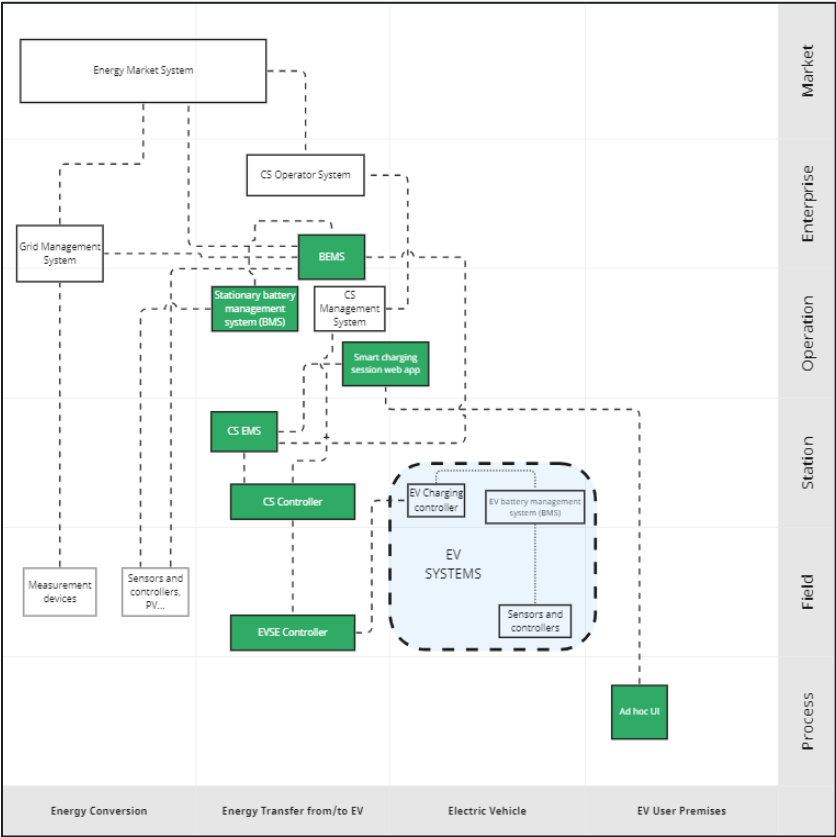


Figure 11 - EMSA Component layer for fork UC1.2 - Amsterdam testing and validation.

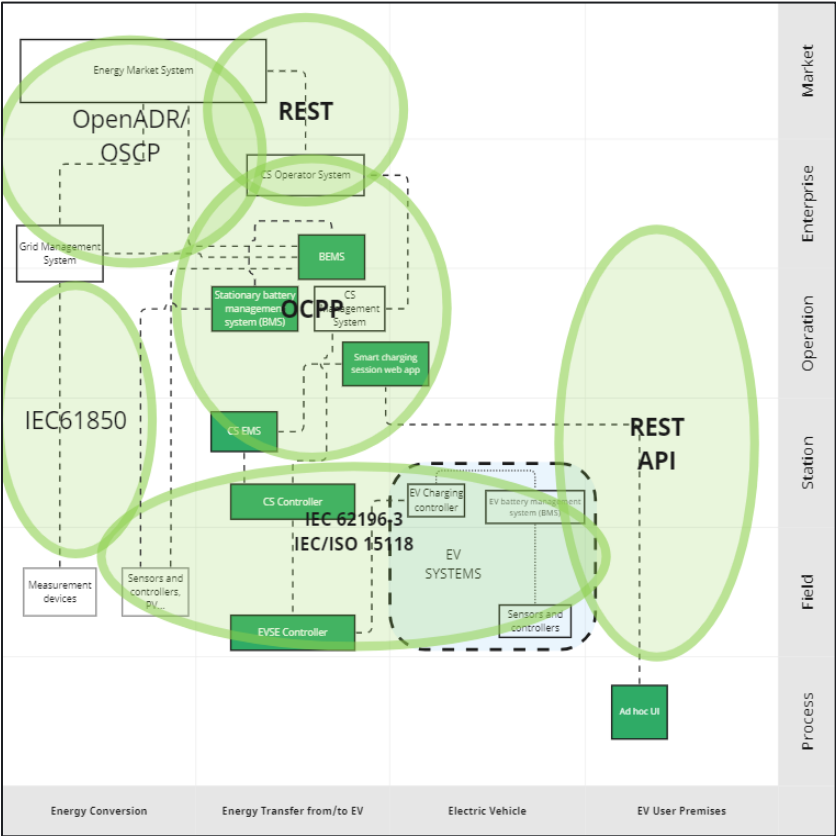


Figure 12 - EMSA Information layer for fork UC1.2 - Amsterdam testing and validation.

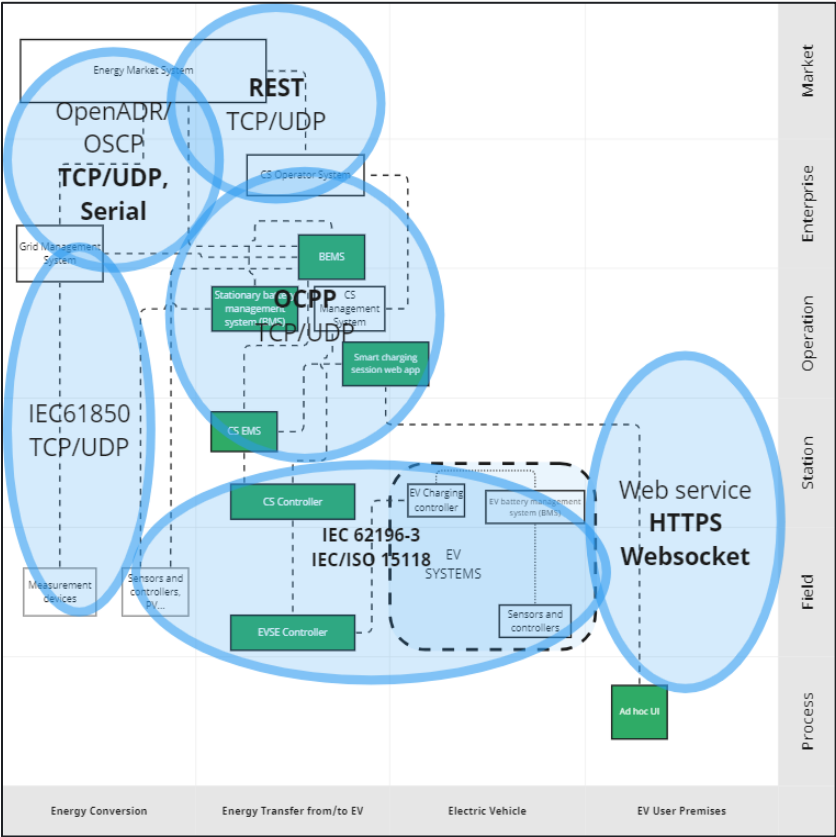


Figure 13 - EMSA Communication layer for fork UC1.2 - Amsterdam testing and validation.

3.1.2.2 Integrated characterization of requirements

A use case is a powerful tool that allows us to understand how users interact with a system or product. It provides a structured way to describe in detail how systems and devices interact and what is user's role in the UC. The following detailed description summarizes the core element of the fork UC1.2 in Table 12. The fork UC1.2 is further developed into stepwise depiction of exchanged information and component use for realization in Table 13. In essence, this depiction captures the conversation between different component involved in the UC.

Table 12 - Detailed framing fork UC1.2 - Amsterdam testing and validation.

Primary actor	EV User
Goals of primary actor	1. Charging of EV, with designated SOC at disconnection time to ensure mobility needs. 2. Offset EV upfront costs by capturing additional value streams from V2B strategies.
Prerequisites	• Integration with existing BEMS • Integration with existing BESS • Commercial CPO operations integration • EV/Charging port and charger protocol compatibility • Technical integration of bidirectionality
Main UC success scenario (User story, primary actor)	Rick arrives to the Amsterdam's arena parking lot for a sports event and plugs vehicle into the charger. He triggers a bidirectional charging session through an ad-hoc user interface. During the charging event, the car's battery is handled under BEMS control together with other resources, such as PV generation, and parallelly to the Stationary BMS, thus contributing to the facility's energy management, as well as enhancing the facility's ability to provide grid congestion relief services at DSO level. To maximize convenience and availability, the car's battery will be either at full charge or at the SOC level that Rick has predefined in the moment of charging event termination. Rick leaves the arena's parking lot after approximately 3h
Linked business model (Primary actor's perspective)	BM2 - Flexibility services offered by EV owners to building managers BM4 - Building tariff optimization leveraged by parking lot smart charging Flexibility services offered by building/facility managers to DSOs Distribution network management through procurement of local V2X flexibility

Table 13 - Stepwise depiction of exchanged information and component use for realization of fork UC1.2 - Amsterdam testing and validation.

Step	Action	Linked information exchange	Linked components' use
1	EV driver arrives to the arena parking area	N.A.	N.A.

Step	Action	Linked information exchange	Linked components' use
2	EV driver plugs car into the bidirectional charger to begin charging event	ISO15118-20 information of the plug-in even	EV charger controller, EVSE controller
3	EV driver interacts with ad-hoc UI	EV charging session creation	Ad-hoc UI, Smart charging session WebApp
3.1	EV driver registers with Drive2X and accepts GDPR, if not accepted earlier.	Acceptance of GDPR and registration	Smart charging session WebApp
4	EV driver inputs information to UI	Estimated departure time and minimum SOC preference	Ad-hoc UI, Smart charging session WebApp
5	EV driver issues confirmation of inputs, which starts charging event	Start of charging command	Ad-hoc UI, Smart charging session WebApp
6	Smart charging web application backend opens charging session and relays information to charger EMS.	Opening of charging session, relay of user input data	Smart charging session WebApp, CS EMS
7	Charger EMS opens charging session in the EMS scheduling application and sends charging event start signal to CS controller	Charging session scheduling, start signal	CS EMS, CS Controller
8	CS controller relays signal to EVSE controller with start charging session according to ISO15118-20 and subscribes to real-time data streams from the vehicle's charging controller and BMS.	Relay of start charging signal, subscription to vehicle data streams	CS Controller, EVSE Controller, EV Charging controller, EV BMS
9	CS controller sends session information upstream and continues relaying CCPP messaging over the charging event	Sends session info upstream, continues OCPP messaging	CS Controller, CS EMS, CS Management System, CS Operator System, Energy Market System
10	CS EMS sends charging session information to building EMS, which optimizes charging session to meet the building's energy balance targets	Sends session info to BEMS for energy resource optimization	CS EMS, BEMS
10.1	BEMS interacts with the energy markets and DSO to acquire data that supports optimization goals	BEMS interacts with Energy Market System and DSO for energy optimization, using OpenADR, OSCP	BEMS, DSO, Energy market system
11	EV driver terminates charging session by interacting with the vehicle's UI (termination from EV charging controller) or with the ad-hoc UI	User-driven charging session termination order	Ad-hoc UI, Smart charging session WebApp, EV Charging Controller
12	The web application backend sends session end signal to CS EMS.	Sends session end signal	Smart charging session WebApp, CS EMS

Step	Action	Linked information exchange	Linked components' use
13	CS EMS terminates charging sessions and sends end signal to CS controller.	Sends end signal	CS EMS, CS controller
14	CS controller sends charging session terminations signal to EVSE controller which terminates charging session with the vehicle unlatching the charging port locking mechanism	Sends termination signal	CS Controller, EVSE controller
15	CS controller sends signal upstream that charging session is terminated	The session has ended	CS controller, CS EMS
16	CM EMS sends session statics to smart charging session web application server that compiles charging statistics report for the UI	Receives session status	CS EMS, Smart charging session WebApp, Ad-hoc UI
17	EV driver may choose to see session's statistics in the UI. EV user is informed of billing. After this, the vehicle is finally unplugged.	Displays charging statistics and billing to user (optional)	Ad-hoc UI, Smart charging session WebApp
18	EV driver leaves the arena parking area	N.A.	N.A.

3.2 UC2 Long-term vehicle-to-building charging with load aggregation in parking lots for dynamic load balancing and building energy management systems' integration

This UC explores win-win smart charging setups when EV users lend their vehicle's battery capacity for building energy management operations for a period between 12h and several days. UC2 will be tested and validated in the Porto Airport demonstrator. For the deployment of the V2B solution, the Building and Parking Managers are the new actors integrated along the standard entities defined by the Portuguese regulation for electric mobility. These two managers are both part of the airport concessionaire (ANA, also a consortium partner of Drive2X), but were intentionally separated for two reasons. The first is to clearly demarcate their scope: the Building Manager is accountable for the energy supervision and control within the airport complex, thus will respond to the power demand of the plugged vehicles and benefit from their capability to provide power to the infrastructure, while the Parking Manager is one of the front ends to the EV users, collecting and processing their parking stay preferences and bill accordingly. The second reason for the separation of these roles is to facilitate the replicability of the solution to other similar hubs where the parking and building management are performed by different organizations.

Among the other entities, the Distribution System Operator (DSO), Charge Point Operator (CPO) and EV Energy Supplier and its acronym in Portuguese, "CEME") are defined by the Regulator. Else, there is the "E-mobility Managing Entity", performed by a single organization (Mobi.e) which, in brief, monitors and manages the charging network in its energy, information and financial flows across EV users, CEMEs, CPOs and DSO. In practice, it allows that an EV user holding a contract with any CEME can charge its vehicle in any publicly accessible charging point despite of its CPO – and for that reason, any charging point located in a publicly accessible venue is required to be connected to Mobi.e. Finally, the Energy Markets are also explicitly represented not due to being much different from the other geographies' markets, but due to its influence in the charge/discharge dynamics between EV and building through the price signals and energy purchasing schemes adopted by both the Building Manager and the CEMEs.

Regarding the CPO role, the Portuguese regulation foresees an entity called, in a free translation, Charging Point Holder, which is an organization that hosts charging points in private access venues (like a restaurant, hotel, or condominiums), but still opts to connect to Mobi.e, allowing the users who can access these chargers to activate and pay for their charging session through their CEMEs, instead of supporting the energy costs itself. Else, and contrarily to a standard CPO, the Holder is not allowed to bill the users for providing and maintaining a charging point. In the Porto Airport case, this means that the Building Manager could become a Charging Point Holder, integrating the operational role of the CPO. This solution can be a turnaround to possible incompatibility issues between CPO and EMS or even V2X solutions. The EV User-Parking Manager interaction, particularly in the compensation for the V2B service, can also happen in different ways. Currently, the one that appears as most feasible is by offering a very low energy cost rate in exchange for its V2B availability. In this way, the Building Manager has more room to maximize savings and the user is benefited by a considerably cheaper charging (while still paying the standard parking tariff).

Table 14 - General framing for UC2 Long-term vehicle-to-building charging with load aggregation in parking lots for dynamic load balancing and building energy management systems' integration.

Use Case coding	UC2
Use Case name	Long-term V2B charging with load aggregation in parking lots for dynamic load balancing and BEMS integration
Technical actors (function-based categorization)	Parking manager (PM), Building manager (BM), EV User, CS operator system, CS management system, CS EMS, CS controller, EVSE controller CEME/EMSP, E-mobility managing entity,
Prerequisites	• Regulatory sandbox from Regulator entity • Pre-installation of infrastructure • Commercial partners collaboration and Integration • Charging port compatibility
Linked demo	Demo 3 – Porto Airport (V2B)
Linked business models (Secondary actors)	BM4 – Building tariff optimization leveraged by parking lot smart charging (Building Manager) BM5 – Flexibility services offered by building/facility managers to DSOs (Building Manager)

3.2.1 Mapping of market and technical requirements

In the context of the EMSA business layer for a V2B long term use case, such as one conceptualized for Porto Airport, the mapping of market requirements necessitates a strategic understanding of the interplay between Evs, energy management systems, and user engagement in a long-term operational scenario.

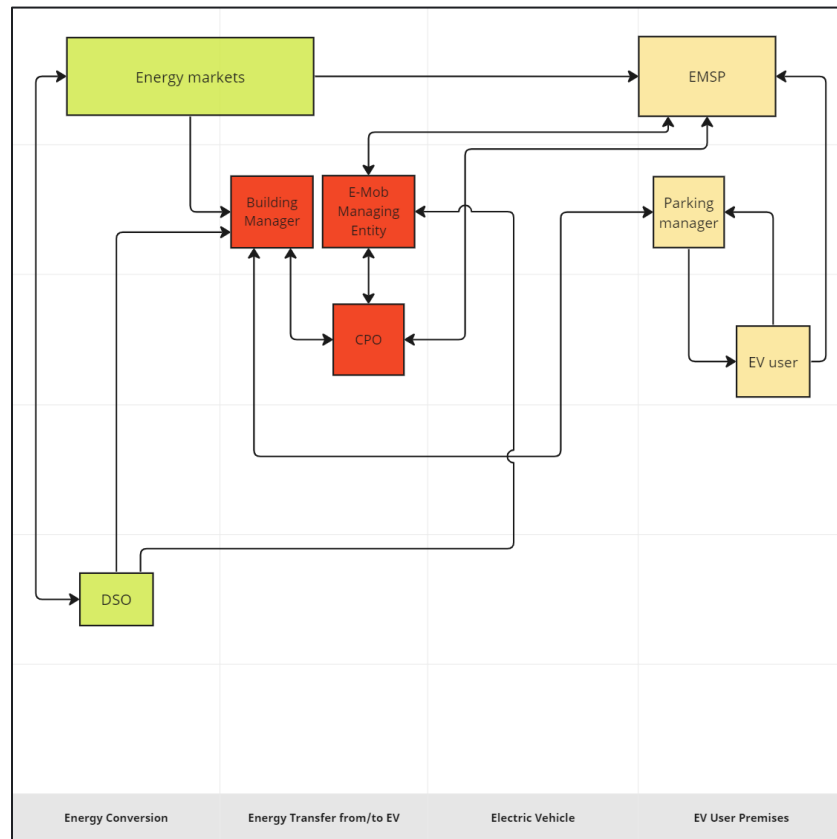


Figure 14 - EMSA Business layer for UC2 - Porto Airport testing and validation.

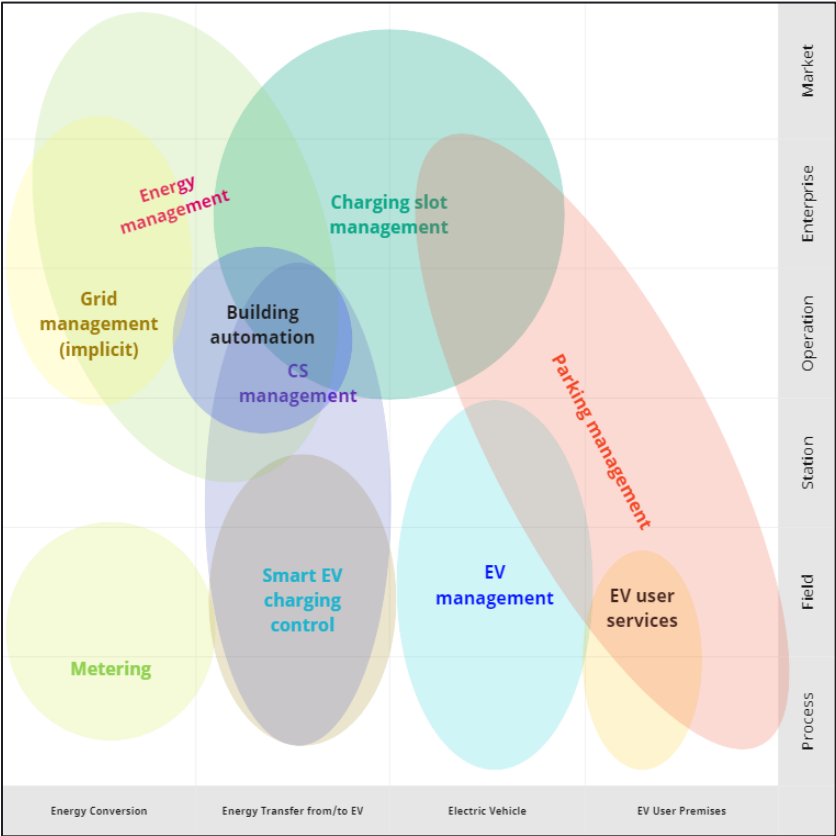


Figure 15 - EMSA Function layer for UC2 - Porto Airport testing and validation.

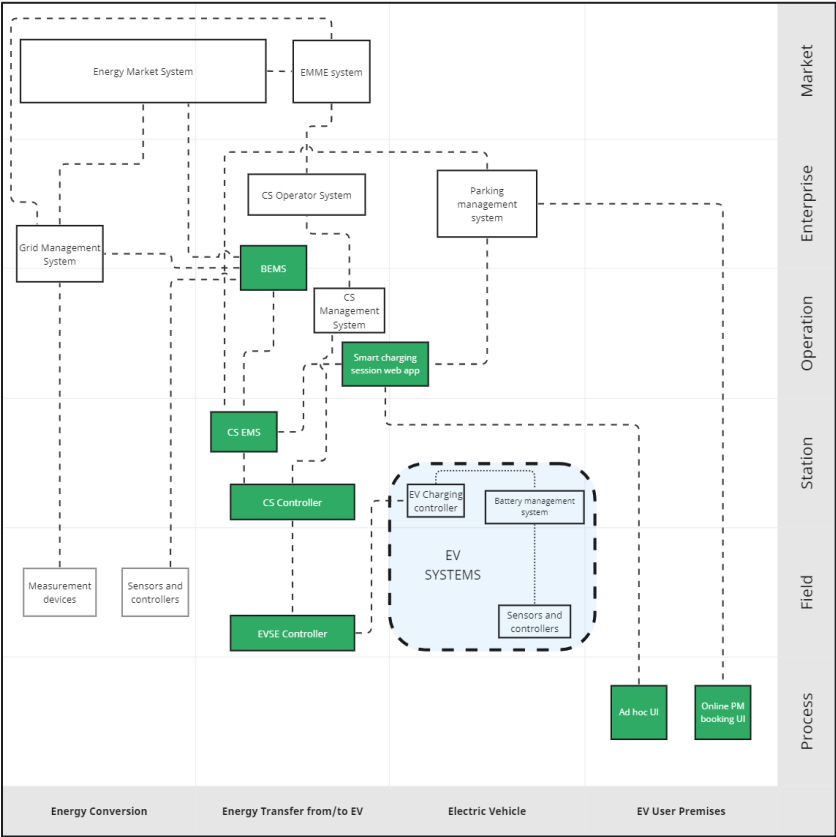


Figure 16 - EMSA Component layer for UC2 - Porto Airport testing and validation.

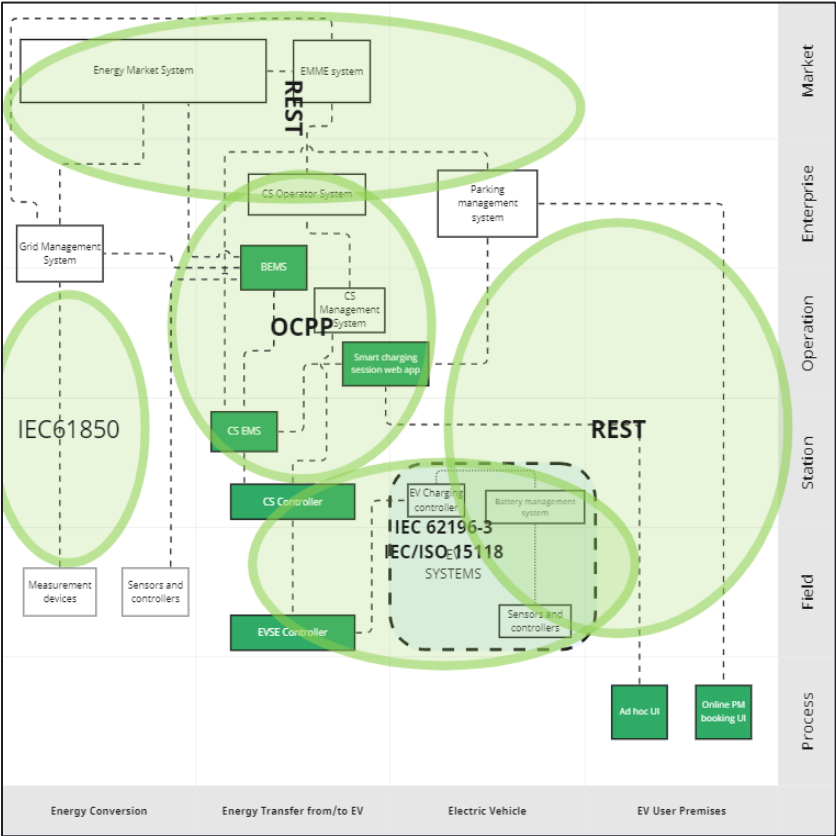


Figure 17 - EMSA Information layer for UC2 - Porto Airport testing and validation.

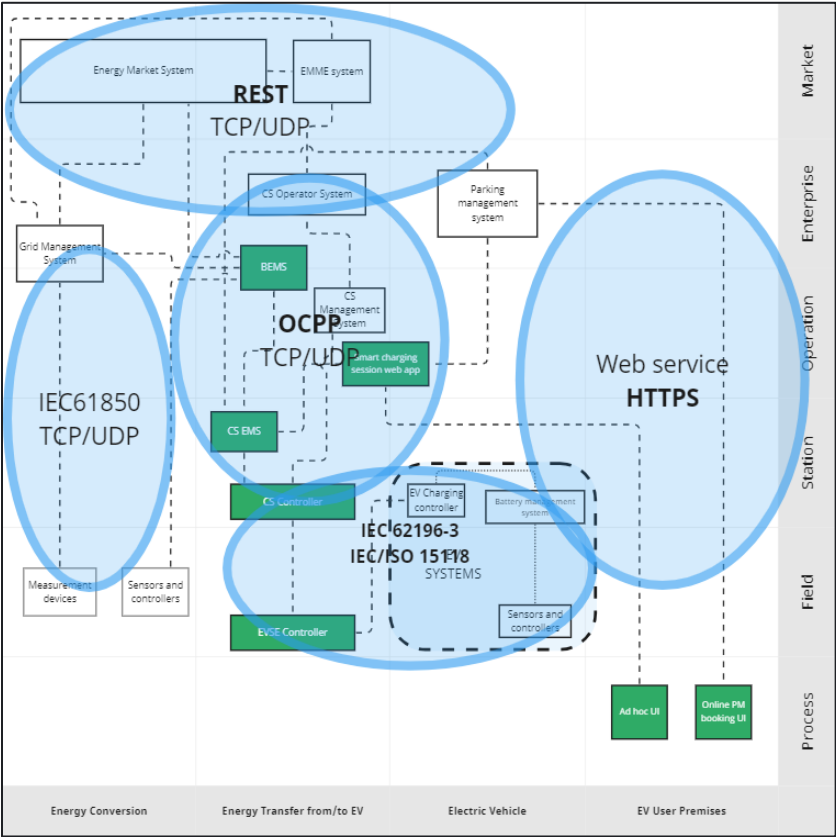


Figure 18 - EMSA Communication layer for UC2 - Porto Airport testing and validation.

3.2.2 Integrated characterization of requirements

A use case is a powerful tool that allows us to understand how users interact with a system or product. It provides a structured way to describe in detail how systems and devices interact and what is user's role in the UC. The following detailed description summarizes the core element of the UC2 in Table 15. The UC2 is further developed into stepwise depiction of exchanged information and component use for realization in Table 16. In essence, this depiction captures the conversation between different component involved in the UC.

Table 15 - Detailed framing for UC2 Long-term vehicle-to-building charging with load aggregation in parking lots for dynamic load balancing and building energy management systems' integration.

Primary actor	EV User
Goal of primary actor	1. Charging of EV, with designated SOC at disconnection time to ensure mobility needs. 2. Offset EV upfront costs by capturing additional value streams from V2B strategies.
Main UC success scenario (User story, primary actor)	Driver prebooks parking or arrives spontaneously to the airports parking area equipped with bi-directional chargers. Car driver plugs car in to the charger and triggers di-directional charging event using ad-hoc user interface. During the charging event car's battery together with charging equipment contributes to buildings energy balance in harmony with other possible energy resources. When the charging event is terminated the car's battery is at full charge or at the predefined target state-of-charge to ensure effortless operation of the car by the driver. The driver leaves airport.
Linked business model (Primary actor's perspective)	BM2 - Flexibility services offered by EV owners to building managers

Table 16 - Stepwise depiction of exchanged information and component use for realization of UC2 - Porto Airport testing and validation.

Step	Action	Linked information exchange	Linked components' use
1	User accesses online parking reservation system from ANA and books (and pays) parking slot, accessing the airport parking lot	Reservation confirmation, payment details	Online Parking Management Booking UI, Parking Management System
2	EV driver plugs car into the bidirectional charger, beginning charging event	ISO 15118-20 information of the plug-in event	EV charging controller, EVSE controller
3	EV user interacts with UI to initiate V2B services, accessing online EV charging web app	Service availability, smart charging session creation	Smart charging session WebApp, Ad-hoc UI

Step	Action	Linked information exchange	Linked components' use
3.1	For enrolment with Drive2X, EV driver accepts GDPR and registers user account (if not done earlier)	Acceptance of GDPR and registration of user credentials	Smart charging session WebApp
4	EV driver inputs smart charging session information	Input of estimated departure time and minimum SOC preference at that time	Ad-hoc UI, Smart Charging Session WebApp
5	EV driver confirms all the inputs, which sends signal to initiate charging session	Start of charging command	Ad-hoc UI, Smart Charging Session WebApp
6	Online charging app sends messaging with data input to CS EMS	Relay of charging requirements, and user preferences' data	Smart charging session WebApp, CS EMS
7	CS EMS in turn signals specifically allocated charger to initiate charging	Charger selection and scheduling, start command	CS EMS, CS Controller
8	Charger and EV Handshake: A communication handshake occurs between the EV and the charging station, initiating the charging session using ISO 15118-20	Handshake confirmation, protocol agreement, vehicle data streams	CS Controller, EVSE Controller, EV Charging controller, EV BMS
9	CS controller sends session information upstream and starts relaying OCPP messaging on charging event	Session information sent upstream, continual OCPP messaging	CS Controller, CS EMS, CS Management System, CS Operator System, Energy Market System
10	CS EMS sends charging session information to BEMS, which initiates optimization of charging session within the boundary conditions to meet building's energy balance targets	Sends session info to BEMS for energy management optimization	CS EMS, BEMS
10.1	BEMS interacts with the energy markets and DSO to acquire data that supports optimization goals	Messaging between BEMS, Energy markets and DSO using OpenADR, OSCP	BEMS, Grid Management System (DSO), Energy market System
11	Event is stopped via user input to the EV charging web app or Ad-hoc UI	Session termination	Ad-hoc UI, Smart charging session WebApp, EV Charging controller
12	The web app backend sends session end signal to CS EMS	Session end signal sent	Smart charging session WebApp, CS EMS
13	CS EMS terminates charging session and sends termination signal to CS controller	Session end signal sent	CS EMS, CS controller

Step	Action	Linked information exchange	Linked components' use
14	CS controller sends charging session terminations signal to EVSE controller, which terminates EV smart charging session and results in unlatching of the charging port (locking mechanism)	Event termination signal sent	CS Controller, EVSE controller
15	CS controller sends signal upstream that charging session is terminated	The session has ended	CS controller, CS EMS
16	CM EMS sends session statistics to Smart charging session WebApp server, which compiles charging statistics report for Ad-hoc UI	Receives session status	CM EMS sends session statistics to Smart charging session WebApp server, which compiles charging statistics report for Ad-hoc UI
17	CM EMS sends session statistics to Smart charging session WebApp server, which compiles charging statistics report for Ad-hoc UI	Receives session status	CS EMS, Smart Charging Session Web App, Ad-hoc UI
18	EV driver is offered possibility of seeing event statistics in UI, and is informed of billing (if applicable), after which vehicle is unplugged	Displaying of charging statistics and billing information to user (by user discretion)	Smart Charging Session WebApp, Ad-hoc UI
19	EV charging web app considers outcomes of smart charging session and informs parking management system of cleared up parking slot	Parking information sent to parking manager	Smart charging session WebApp, Parking Management System
20	User leaves airport	N.A.	N.A.

3.3 UC3 Vehicle-to-home integration with home energy management systems for renewables' integration and tariff optimization in prosumer and consumer homes

The goal of UC3 is to analyze the impact and value of bidirectional EV charging in the residential environments, particularly involving home automation and energy market interaction optimization. This UC is tested in Demo 5 - Budapest City V2H demonstrator.

The Drive2X Budapest V2H demonstrator will investigate the enhanced role bidirectional EV charging could play in the energy affairs of consumer and prosumer homes. When integrated into homes, EV batteries become a DER asset at the service of the HEMS. The aspect of bidirectionality allows for reduced energy consumption (especially during peak hours), stabilization of demand on the grid, and active contribution to grid flexibility through implicit demand response. In addition, homeowners could reduce their energy costs substantially, by performing time-of-use tariff optimization.

The demo will install 10 Drive2X single-phase bidirectional EV chargers in homes spread across different neighborhoods of Budapest city center and suburbs. To better understand the nuanced impacts of V2H

strategies, the selection of recruited homes will consider a mix between electricity customers with installed DER (prosumers) and electricity customers without it (consumers). Recruited homes will need V2X-compatible EVs, which are scarce in Hungary, and the best approach to handle this is still being studied. The involvement of the villanyautosok.hu community has been discontinued and the SFC team is now resorting to the social networks to drive influence and attract participation. SFC has identified that a growing class of Hungarian homeowners who own rooftop PV are keen on deploying complementary storage solutions but being barred by high CAPEX. In addition, the current regulatory situation encourages electric mobility, due to non-refundable state support to EV purchases and various benefits EV drivers now enjoy, such as free parking and tax benefits.

Table 17 - General framing for UC3 Vehicle-to-home integration with home energy management systems for renewables' integration and tariff optimization in prosumer and consumer homes.

Use case coding	UC3
Use Case name	V2H integration with HEMS for renewables' integration and tariff optimization in prosumer homes.
E-mobility market actors (Aligned with EMSA Business layer)	Home manager/Prosumer/Consumer, EV user (who could also be, but not necessarily, the latter), DSO, and "Energy Markets", as a broad category, which in this demonstrator essentially represents Electricity Retailers
Technical actors (Aligned with EMSA Component layer)	EVSE Controller, EV Charging controller, CS Controller, HEMS, Grid Management System, Energy Market System
Prerequisites	- V2X capable EV and charger (ISO 15118 standard) - Separately installed circuit breaker for the charger - PV installed (with inverter in case of AC-DC chargers) - In case the home is also grid connected (grid or semi-island mode), circuit breakers with at least 3 phases, at least 20A each installed between home and grid
Linked demo	Demo 5 – City of Budapest (V2H)
Linked business models (Secondary actors)	BM1 - Flexibility services offered by EV owners or prosumers to network operators (DSO) BM5 - Flexibility services offered by building/facility managers to DSO (Building manager)

3.3.1 Mapping of market and technical requirements

In the V2H use case represented in the Budapest scenario, the EMSA business layer maps out a market structure that focuses on the integration of EVs with home energy management systems. This approach is rooted in the objective to synergize the operation of household energy consumption with the energy storage capacity of EVs to optimize the use of renewable energy sources and energy tariffs.

In this use case, the EMSA business layer identifies four principal market players: the Energy Markets, the DSO, the Home Manager, and the EV User within the homeowner category, which encompasses both prosumers and consumers.

The Energy Market provides Time-of-Use (TOU) tariffs that are essential for the effective optimization of Home Energy Management Systems (HEMS) and the integration of V2H. These tariffs enable homeowners to

make economically advantageous decisions about when to consume, store, or feed energy back into the grid, thereby promoting the adoption of HEMS and V2H technologies.

The Home Manager operates at the nexus of energy management within the residential setting, utilizing these TOU tariffs to optimize energy use. This role is critical whether the homeowner is a prosumer, generating their own renewable energy, or a consumer, primarily drawing energy from the grid. For both, the EV plays a dual role as a transport tool and an energy storage unit that participates in the home's energy economy, influenced by the TOU tariff structure.

The DSO, while indirectly engaged, plays an enabling role by connecting the home to the electric infrastructure and benefiting from the enhanced flexibility that optimized home energy operations provide. Homes, especially those of prosumers, evolve into more adaptive electricity consumers under this model, capable of responding to the DSO's energy price signals and contributing to a more balanced and responsive grid.

By focusing on these interactions and incentives, the V2H use case in Budapest outlined in the EMSA business layer proposes a market structure that encourages the integration of electric vehicles into home energy systems, fostering a shift towards more efficient and economically sustainable energy usage in residential spaces. This structure is geared towards harnessing the full potential of V2H interactions, enhancing the energy autonomy of homeowners, and contributing to the overall stability and efficiency of the energy grid.

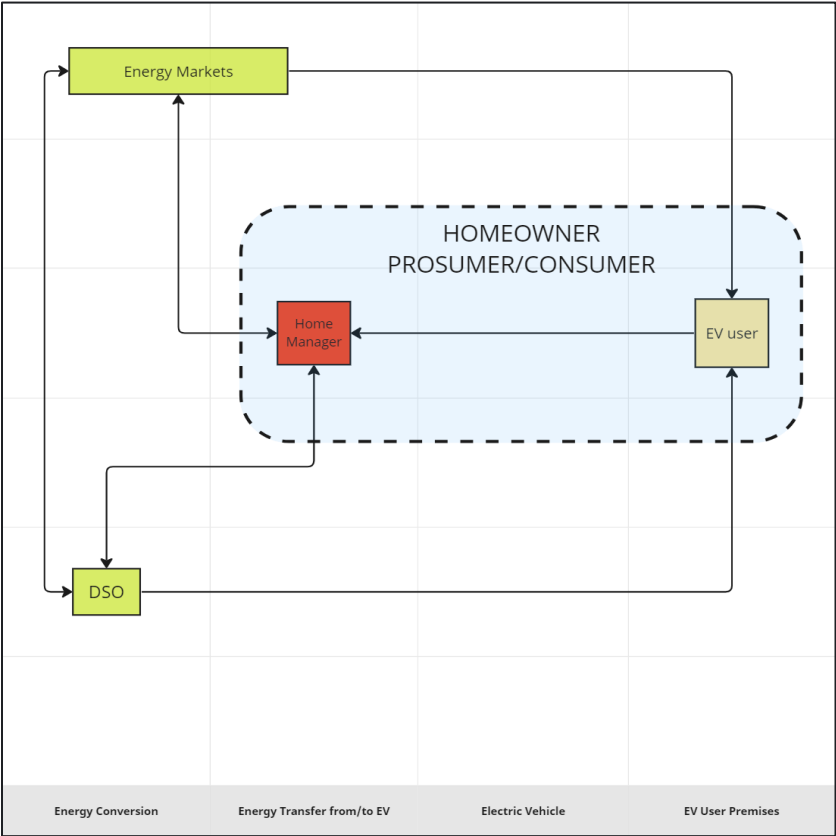


Figure 19 - EMSA Business layer for UC3 - Budapest testing and validation.

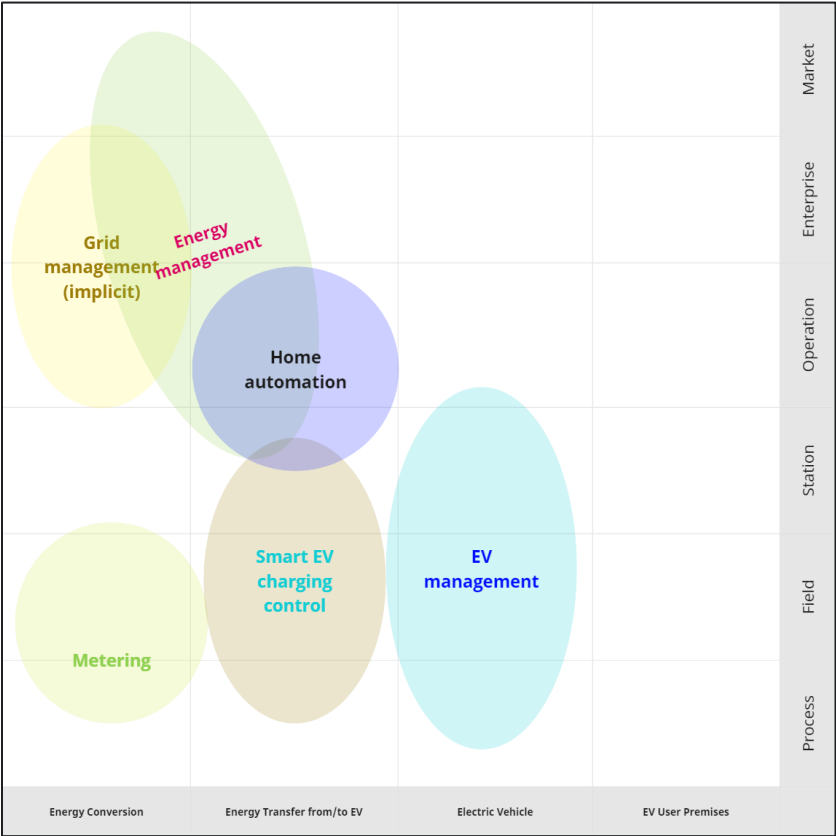


Figure 20- EMSA Function layer for UC3 - Budapest testing and validation

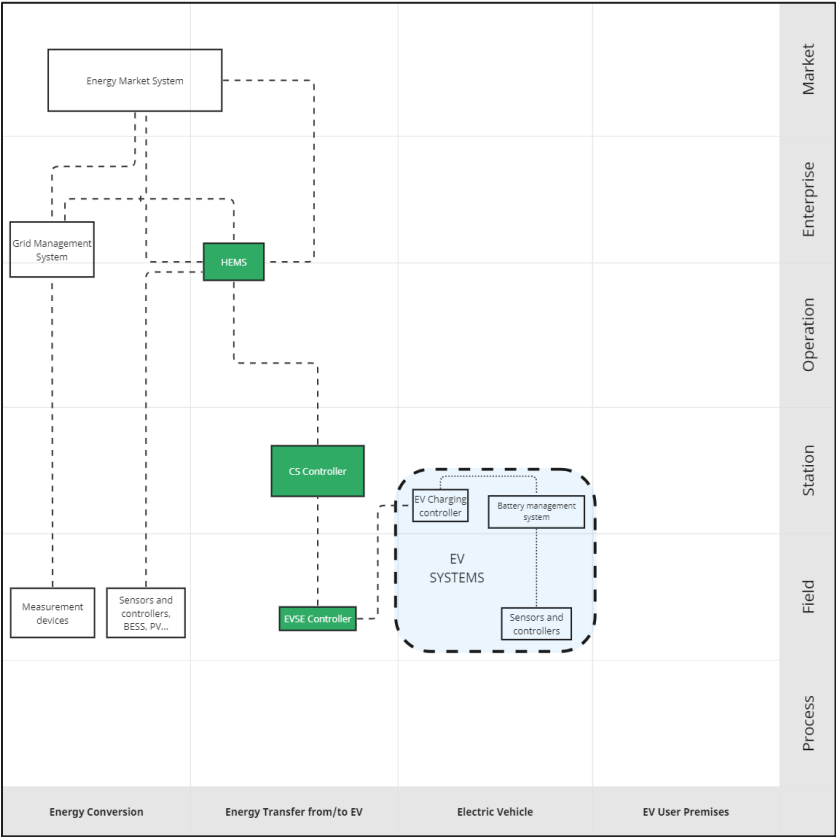


Figure 21- EMSA Component layer for UC3 - Budapest testing and validation

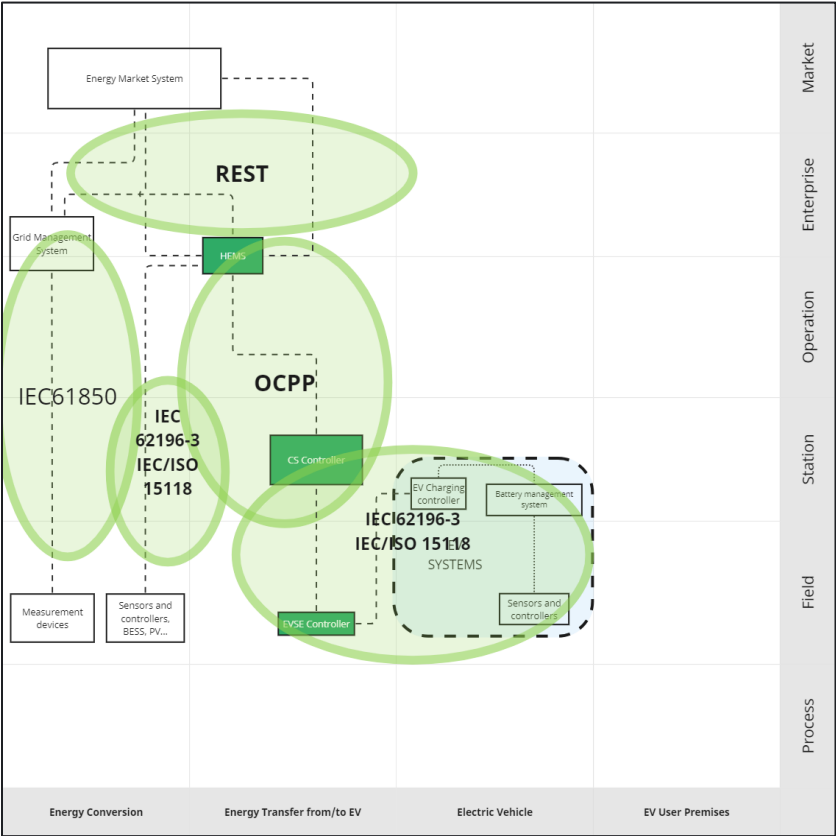


Figure 22- EMSA Information layer for UC3 - Budapest testing and validation.

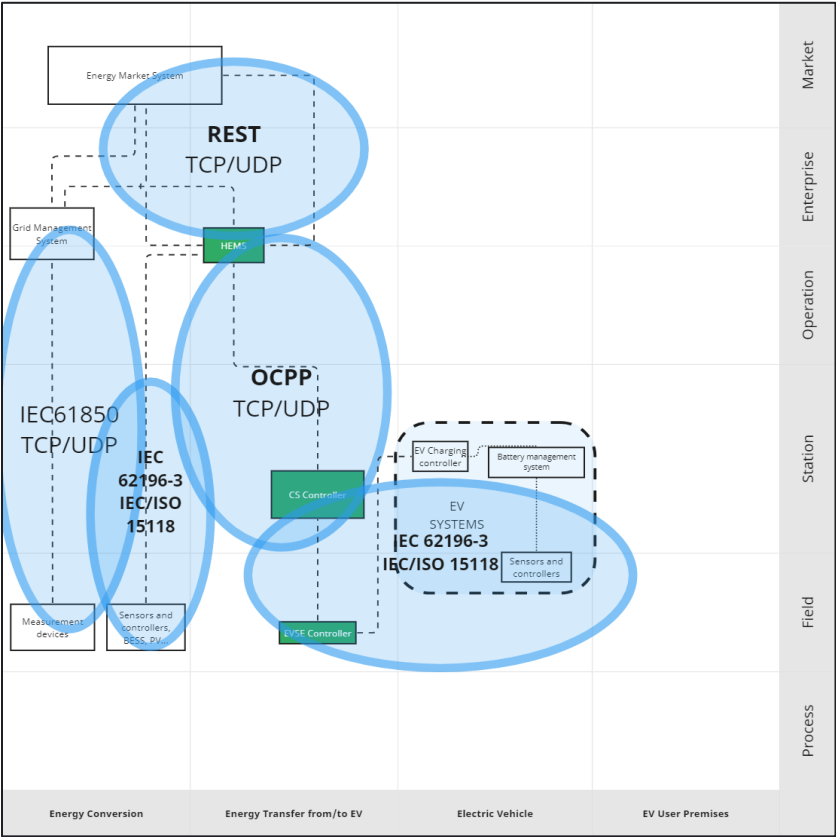


Figure 23- EMSA Communication layer for UC3 – Budapest testing and validation.

3.3.2 Integrated characterization of requirements

A use case is a powerful tool that allows us to understand how users interact with a system or product. It provides a structured way to describe in detail how systems and devices interact and what is user's role in the UC. The following detailed description summarizes the core element of the UC3 in Table 18. The UC3 is further developed into stepwise depiction of exchanged information and component use for realization in Table 19. In essence, this depiction captures the conversation between different component involved in the UC.

Table 18 - Detailed framing for UC3 Vehicle-to-home integration with home energy management systems for renewables' integration and tariff optimization in prosumer and consumer homes.

Primary actor	EV User
Goals of primary actor	1. Charging of EV to enable user mobility, disconnection SoC preference being user-defined 2. Offset EV upfront costs by optimizing tariff use and thus obtain energy savings from V2H strategies
Prerequisites	Home is equipped with the HEMS, bi-directional charger and proper integration is established to enable functionality. The regulatory framework allows tariff structures that creates motive to optimize energy usage.
Main UC success scenario (User story, primary actor)	John drives his EV home from work on a Friday at around 6pm. When he arrives home, he connects his vehicle to the bidirectional home charger. Because John works close by, the battery SoC is still at 70%. According to John's preferred HEMS control logic, the HEMS will start powering the home with the EV battery during expensive electricity "shoulder hours" (approx. between 6pm and 8pm). The home then recharges the EV battery to its full SoC during off-peak periods of the early morning (when electricity is cheapest). On early Saturday morning, the home is again powered by the EV, which is convenient due to the family's demand peak on that day. During the next hours of the morning, the HEMS instructs the PV system to recharge the vehicle with clean, free electricity (according to John's preference). Later that day, John and his family leave home for lunch out, with the EV battery once again at full SoC.
Linked business model (Primary actor's perspective)	BM1 - Flexibility services offered by EV owners or prosumers to network operators BM3 - Prosumer tariff optimization leveraged by residential smart charging

Table 19 - Stepwise depiction of exchanged information and component use for realization of UC3 - Budapest testing and validation.

Step	Action	Linked information exchange	Linked components' use
1	EV driver arrives home	N.A.	N.A.
2	EV driver plugs-in vehicle to bidirectional charger, initiating charging event and real-time data streams from the vehicle's charging controller and BMS	ISO 15118-20 (or CHAdeMO) handshake and communication	EVSE Controller, EV Charging controller, EV BMS
3	EV charger communicates user-driven start of charging event to CS controller	Charging session start signal	EVSE Controller, CS Controller
4	CS controller sends session information to HEMS and starts relaying OCPP messaging on charging event	Session information sent upstream, continual OCPP messaging	CS Controller, HEMS
5	The HEMS communicates with the charger to perform smart charging and optimize the home's energy balance. However, the EV battery may or not be always available for energy management. Table 20 elaborates on possible SoC scenarios and respective actions that may dictate battery availability.	Real-time information exchange to enable HEMS operation. Authentication of user and vehicle (needed to collect data during the pilot).	HEMS, CS Controller, EVSE Controller
5.1	The HEMS interacts with the energy markets and DSO to acquire data that supports optimization goals. See further Table 20,	Messaging between HEMS, Energy markets and DSO using OpenADR, OSCP	HEMS, Grid Management System (DSO), Energy market System
6	EV driver terminates charging event by interacting with the vehicles UI. Termination process results in charger port unlocking	Charging termination signal from the car to EVSE, CS controller and HEMS	CS controller, EVSE Controller, EV charging controller
7	EV driver disconnects charging cable	User-driven session termination	EVSE Controller, EV charging controller
8	EV driver leaves home	N.A.	N.A.

Table 20 - Operational EV and EVSE charging decision possibilities based on EV battery SoC.

Step	Action	Linked information exchange	Linked components' use
1A	SoC determines the need for charging	The HEMS and EV negotiate the charging rate. Factors like available power capacity, battery health, and time	EV Charging controller, EVSE Controller, EV BMS, HEMS

		constraints influence this negotiation. IF use of battery is possible, EV signals the charger to start charging, and HEMS is informed	
1B	SoC determines there is no need for (more) charging.	EV signals the charger to stop charging, and HEMS is informed	EV Charging controller, EVSE Controller, EV BMS, HEMS
2	Discharging is needed from the connected vehicle and SoC allows discharging.	EV signals the charger to initiate charging, and HEMS is informed	EV Charging controller, EVSE Controller, EV BMS, HEMS
2A	Discharge stopped because of SoC interrupt.	EV signals charger to stop discharging, relaying message to HEMS	EV Charging controller, EVSE Controller, EV BMS, HEMS
2B	Discharge interrupted by user intervention.	User-driven interruption via EV UI. EV Controller informs charger, which passes on message to HEMS.	EV Charging controller, EVSE Controller, EV BMS, HEMS
2C	Discharge stopped as there is no need for more stored energy.	EV signals charger controller to stop discharging, and HEMS is informed	EV Charging controller, EVSE Controller, EV BMS, HEMS
2D	Discharge stopped due to anomaly	The charger continuously monitors safety parameters such as voltage, current, and temperature. If any anomalies are detected (e.g., overheating, short circuits), the charger interrupts the charging process.	EV Charging controller, EVSE Controller, EV BMS, HEMS

3.4 UC4 Vehicle-to-grid integration in public charging stations for addressing technical grid constraints

This UC looks into vehicle-to-grid operations in direct interaction with the distribution grid, and offering possible benefits that improve the grid management activities of network operators (DSOs/DNOs). The UC is tested in three environments, which are Demo 2 – Isle of Wight V2G, Demo 4 – Maia city centre V2G, and Demo 7 – Terni city centre V2G.

Table 21 - General framing for UC4 Vehicle-to-grid integration in public charging stations for addressing technical grid constraints.

Use case coding	UC4
Use Case name	V2G integration in public charging stations for addressing technical grid constraints
Technical actors (function-based categorization)	EV user, EMSP, DSO, CPO, Clearing House, Local Market Platform, Energy Markets, Fleet Manager, EMME (Portugal)
Prerequisites	EV owner has registered to application having already input personal details data Pre-Session Energy Forecasting: Before users even engage with the V2G system, the E-Mob Managing Entity could perform predictive analytics to forecast energy demand and supply needs for the upcoming period. Grid Needs Assessment: A step where the DSO evaluates the grid's current and upcoming energy requirements, which could influence the timing and scale of V2G services requested. Real-Time Monitoring: Continuous monitoring of the V2G session to ensure compliance with the set parameters and to adjust in real-time to any unforeseen changes in grid demand or vehicle needs.
Linked demo	• Demo 2 – Isle of Wight (V2G) • Demo 4 – Maia city centre (V2G) • Demo 7 – Terni city centre (V2G)
Linked business models (Secondary actors)	BM1- Flexibility services offered by EV owners or prosumers to network operators BM6 - Distribution network management through procurement of local V2X flexibility

3.4.1 UC4.1 Isle of Wight V2G testing and validation environment

The Isle of Wight V2G demo will integrate bidirectional EV charging into the island's distribution network with view to provide flexibility and support grid stability, especially when in presence of high penetration of intermittent solar generation and as a means to avoid curtailment events. With support from FloW and local DNO SSEN, Drive2X will deploy five 20 KW V2G chargers across selected public EV charging stations.

Participant EV users will possibly be recruited from a "car club" with whom Drive2X will partner. To enable the demo, the car club will be temporarily trusted with several V2G-compatible vehicles to be leased by FloW from an EV manufacturer company. Car club vehicle users could be local resident subscribers or occasional tourist users. When not in use, these EVs will be parked at public charging stations and generate revenue from distribution network support services that are of interest to the local DNO. In this win-win, the car club seeks a complementary revenue stream to car rental revenues, which could currently be limited as a result from either low population density and/or tourism seasonality, whereas the DNO gets grid management

support from an alternative and distributed source of flexibility, which helps mitigate the challenges of integrating renewable energy sources and maintaining grid stability. For residents and tourists alike, the use of car club EVs offers convenience and a lower cost alternative to own vehicle use or traditional car rentals.

The integration of bidirectional EV charging flexibility into an existing marketplace in the Isle of Wight's V2G demonstrator needs better understanding by the project team. In the UK, aggregation platforms for smart charging and V2X flexibility have already been partially rolled out, especially in domestic environments. These platforms have their own UI, essentially operating as EMSPs intermediating EV energy supply and flexibility services to the DNO, including respective transaction and billing services. However, the level of possible compatibility for integration of Drive2X technologies, particularly taking it into the public V2G charging sphere, is still under assessment. Specific grid services to be provided to the DNO would be under the auspices of the existing platform, and exactly which services these platforms manage and its alignment with Drive2X objectives is not yet known. Aspects of monetary compensation under Drive2X also need better definition and alignment, since they are already in force for some flexibility services offered by these platforms. If an V2G flexibility aggregation platform cannot be accessed in the demo, then it is likely that access to public charging stations will have to be ensured through involvement of a traditional EMSP. The EMSP would have a central role in enabling various features of the marketplace, enabling the charging service through its UI and intermediating the sale of charging electricity by an EV energy supplier. Grid services could still need to be intermediated by a small-scale flexibility aggregator and this operation would be taking place in the background of DNO grid support. Lastly, the EMSP is responsible for seamlessly managing payment and billing of CPO and aggregator services fees, EV energy supply electricity, and EV user compensation for provision of DNO grid support services, thus maintaining the system's economic viability. Partnerships with local CPOs in charge of selected charging stations and where Drive2X bidirectional chargers will be installed also need to be established. In this context, the demo needs to strike a balance between the services that the project consortium will provide and integrate into the existing charging station management systems, and the services that incumbent CPOs will continue to offer.

3.4.1.1 Mapping of market and technical requirements

The V2G demonstration on the Isle of Wight explores the grid flexibility advantages that arise from integrating V2G technology into RES-congested grids aiming to avoid curtailment events and support grid stability. Simultaneously, it delves into the potential of V2G implementation on local economic activities and tourism on the island.

EMSP ensures smooth payment and billing processes for CPO and aggregator service fees. It provides user interface to EV users in which they are also billed for DSO energy supply services. Compensating EV users for providing DSO grid support services and CPO for charging station services, the EMSP upholds the economic sustainability of the system. The CPO in turn supplies charging session data to the EMSP.

The CPO oversees the technical management of the charging infrastructure, while the DSO operates and upkeeps the grid. Consequently, these entities must exchange information to ensure the allocation of suitable capacity for charging purposes. Essentially, the CPO is tasked with accommodating the combined EV charging profiles within the constraints of the available capacity.

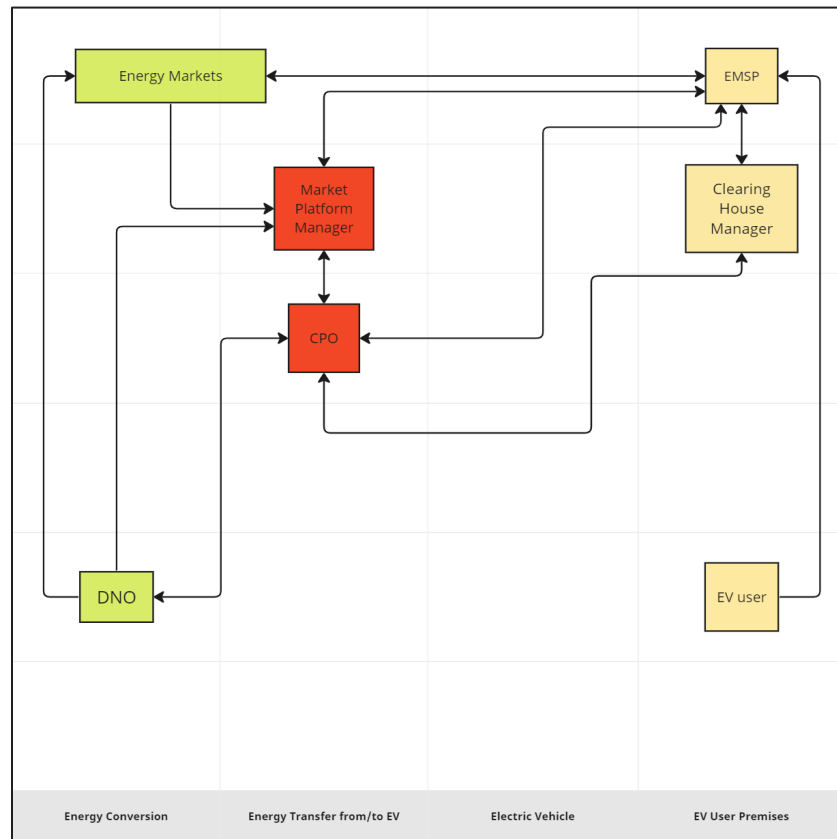


Figure 24 - EMSA Business layer for fork UC4.1 - Isle of Wight V2G testing and validation.

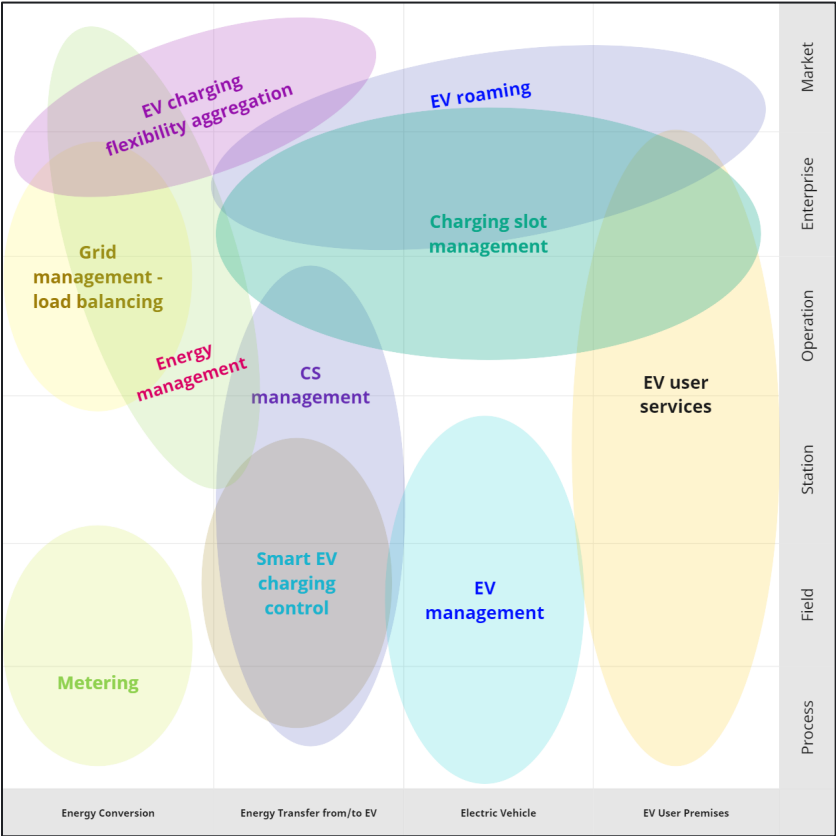


Figure 25 - EMSA Function layer for fork UC4.1 - Isle of Wight V2G testing and validation.

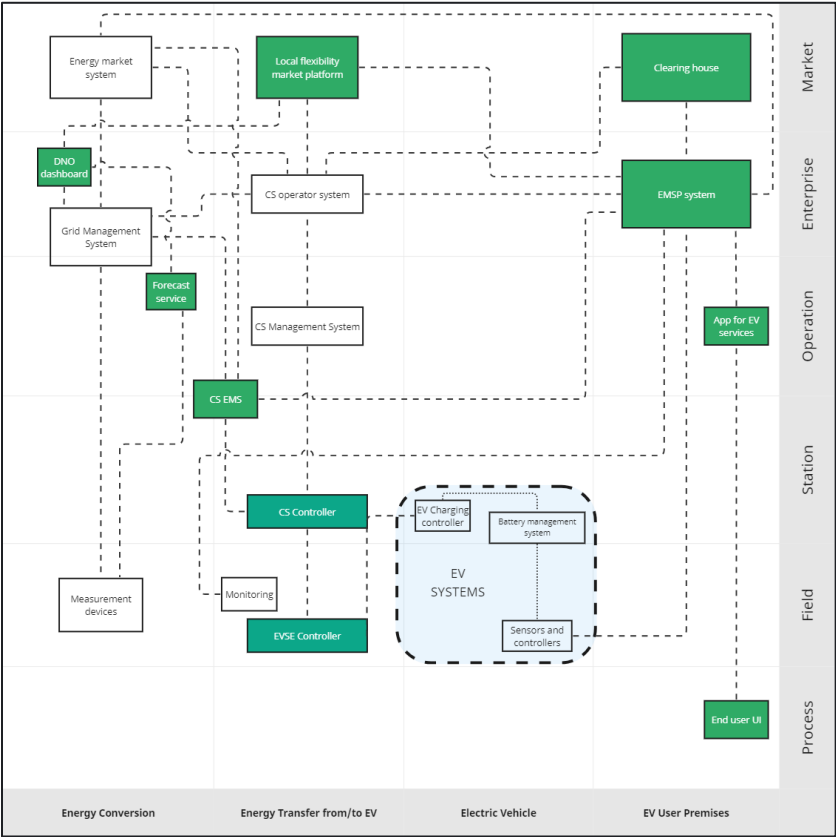


Figure 26 - EMSA Component layer for fork UC4.1 - Isle of Wight V2G testing and validation.

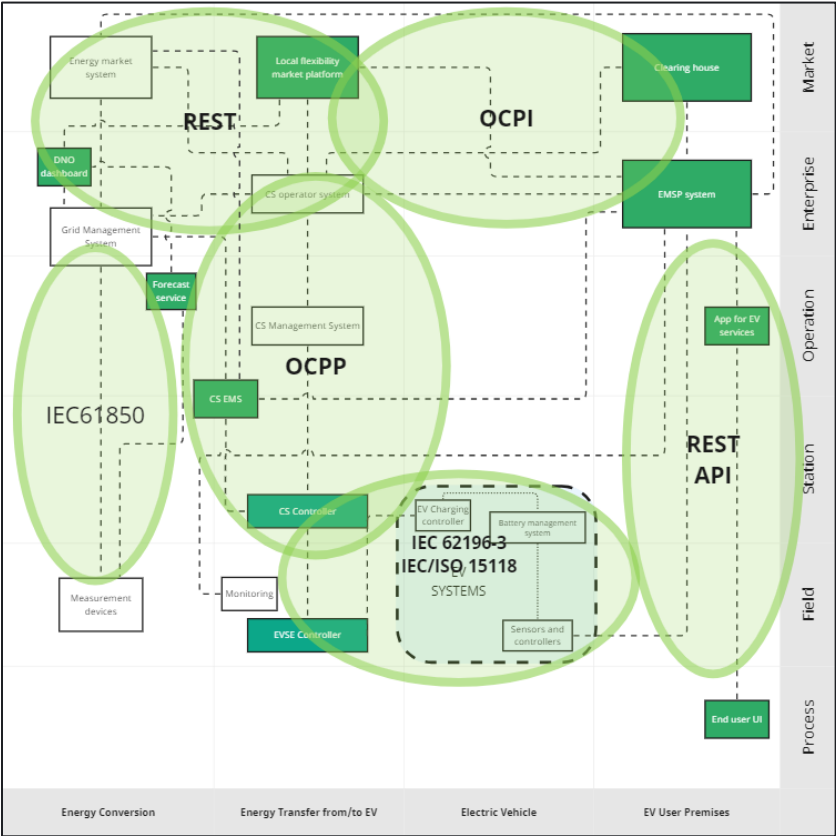


Figure 27 - EMSA Information layer for fork UC4.1 - Isle of Wight V2G testing and validation.

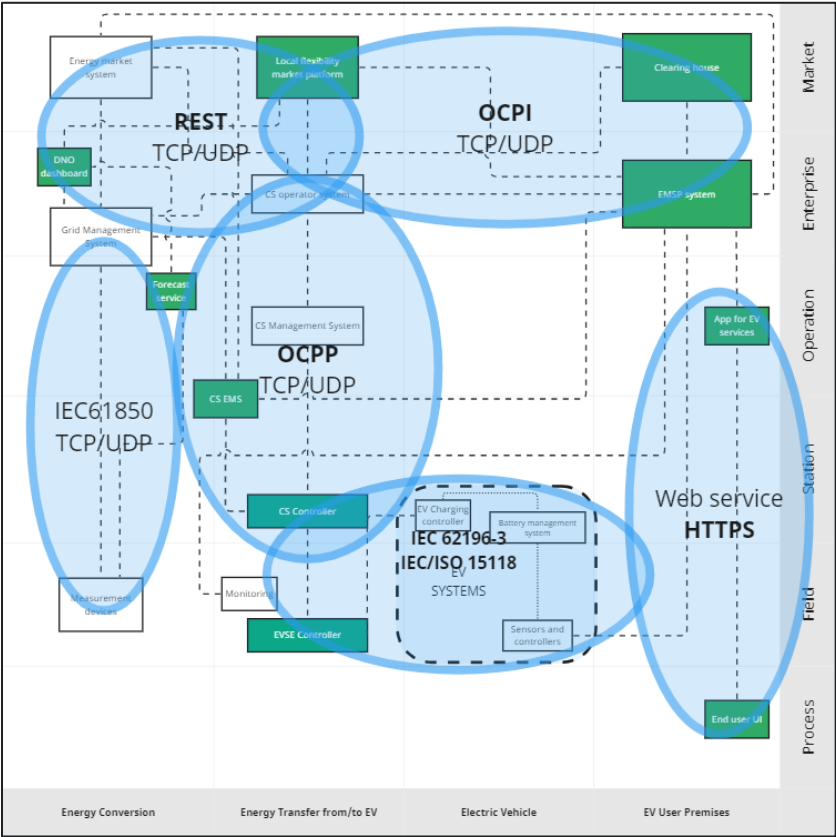


Figure 28 - EMSA Communication layer for fork UC4.1 - Isle of Wight V2G testing and validation.

3.4.1.2 Integrated characterization of requirements

A use case is a powerful tool that allows us to understand how users interact with a system or product. It provides a structured way to describe in detail how systems and devices interact and what is user's role in the UC. The following detailed description summarizes the core element of the fork UC4.1 in Table 22. The fork UC4.1 is further developed into stepwise depiction of exchanged information and component use for realization in Table 23. In essence, this depiction captures the conversation between different component involved in the UC.

Table 22 - Detailed framing for fork UC4.1 Vehicle-to-grid integration in public charging stations for addressing technical grid constraints - Isle of Wight V2G testing and validation.

Primary actor	EV user
Goal of primary actor	1. Charging of EV, with designated SOC at disconnection time to ensure mobility needs. 2. Offset EV upfront costs by capturing additional revenue streams from V2G services.
Main UC success scenario (User story, primary actor)	Thomas uses an EMSP UI to identify an available charging point. He drives his EV to that public charging station and plugs it into the charger. Through the UI, Thomas is invited to participate in a DSO flexibility campaign that may provide revenues from V2G services. He accepts to do so, triggering a bi-directional charging session. During the smart charging event, the car's battery through the charging equipment offers demand/supply balancing to the distribution grid, with various charging/discharging cycles. When the charging event is terminated, Thomas' car's battery is at full charge or at the predefined target SoC to ensure the least disruptive operation possible of the car and that mobility goals are reached. Thomas is notified by the EMSP UI of how much revenue he made from V2G services. He then drives off from the charging station.
Linked business model (Primary actor's perspective)	BM1- Flexibility services offered by EV owners or prosumers to network operators BM6 - Distribution network management through procurement of local V2X flexibility

Table 23 - Stepwise depiction of exchanged information and component use for realization of fork UC4.1 - Isle of Wight V2G testing and validation.

Step	Action	Linked information exchange	Linked components' use
1	EV driver arrives to the parking area	N.A.	N.A.
2	EV driver plugs car in to the bi-directional charger to begin charging event	ISO15118-20 information of the plug-in even	EV charger controller, EVSE controller
3	EV driver interacts with ad-hoc UI or alternatively with EMSP provided mobile app	Session creation	Ad-hoc UI, Smart charging session webapp

4	EV driver opts for bi-directional charging and accepts DPA notice (registers if not already registered)	User-UI interaction	EVSE Controller
5	EV driver sets estimated departure time and preferred SOC at the time of the departure.	Departure time, SOC	UI, CS management system, App for EV Services
6	The EV driver starts charging event using UI	User-UI interaction	EVSE Controller, EV Charging controller
7	EMSP UI backend processes request and sends start signal to CPO while also creating charging session	Confirmation of charging session initiation	EMSP, CS Operator system
8	CPO send start signal to downstream via OCPP framework to CS controller which creates charging session and trigger start signal to EVSE controller.	Command to start charging and data flow,	CS Controller, CS Management system, CS operator System
9	EVSE controller initializes session with the vehicle and subscribes real-time data streams according to ISO15118-20.	data streams according to ISO15118-20	EVSE controller, CS Controller
10	EMSP initializes session with clearing house, local flexibility market platform, and DNO dashboard to start bidding for flexibility offers. The flexibility allocation and related optimization is implemented with dedicated applications under EMSP system.	Bidding for flexibility and optimization of energy resources	EMSP, Clearing House, DNO dashboard, local flexibility market platform.
11	EMSP gets real-time data of the charging event via CPO and continues interacting with the vehicle.	Monitoring of charging process and real-time data acquisition	EMSP, CS EMS
12	Event is stopped via user input to the EV charging control system, and communicates session termination to the EVSE controller, which subsequently informs CS management, and EMSP. Alternatively we charging event can be stopped via EMSP mobile app.	Termination of charging session	EVSE controller, CS management, and EMSP UI
13	EV charging web app summarizes the charging statistics and performs billing to the appropriate participants	Calculation of charging statistics and processing of payment	EV charging web app
16	EV driver leaves the area	N.A.	N.A.

3.4.2 UC4.2 Maia V2G testing and validation environment

The Maia V2G demonstrator will test smart charging in urban areas and investigate the value of short-term V2G strategies for load balancing and control of technical parameters (such as voltage) in distribution networks. The demo will integrate two 20 kW bidirectional chargers in an existing EV charging facility located in the city centre, the e-hub. Built in 2021, the e-hub was the first, as well as the largest municipal charging facility equipped with fast charging in Portugal. It currently includes 8 EV chargers, one of them being a fast charger. The selection of this location was done together with the Municipality of Maia, considering various criteria, such as availability of charging slots and respective connection infrastructure, convenience to users and their expected charging habits, and visibility of the charging station and project initiative. The

municipality of Maia is in full support and acts as an enabler of the demonstrator, which also strengthens its energy transition goals for the region.

Access to the e-hub charging station is public, and thus recruiting EV user participants from the within the city and its outskirts will be necessary. The municipal government and the Electric Vehicle Users Association of Portugal (UVE) have tentatively agreed to support the consortium in this task, despite these developments being still preliminary. The possibility of offering free charging as possible compensation for user participation is currently being studied.

To realize this demo in a public space, it will be necessary to partner with a local CPO, who would ideally support the charging station operation and maintenance activities. Still, some CPO services could remain in the realm of the Drive2X consortium. It is likely that that tradeoff will be a result of negotiations and conditions for involvement advanced by the CPO, but this process has not started yet. The involvement of an EMSP could only be facilitated if its systems have some level of ability to integrate V2G charging, but it is not yet known if this is the case. More likely, and ideally, the Drive2X consortium will provide the UI and backend systems (just like in the V2B demos) to access the chargers and remaining E-mobility services.

Drive2X will engage the incumbent DSO to study the value of the provision of power and energy-based grid support services from V2G. Since a framework for such services in context of bidirectional charging does not exist in Portugal, the technical model for realizing those grid benefits needs to be further discussed, taking in into consideration that the two chargers will be implemented in an existing charging circuit. One possibility to assess is evaluating implicit load balancing and e.g. voltage support within the charging station facility, which would result in indirect congestion relief benefits at distribution transformer level. Lastly, CEME contracts need to be established for EV charging supply. In Portugal, the CEME entity must be a CPO, and given this, the same actor should ideally be involved. The EMME regulates the entire process, ensuring that the Maia demonstrator is linked to the system and in full compliance with market transparency and competition rules.

3.4.2.1 Mapping of market and technical requirements

The business layer of this use case aims elucidate the market dynamics and economic opportunities associated with use case 4.1 represented by demonstrator Maia city center. Market participants within this use case leverage the inherent flexibility of EVs in a public e-hub charging station, utilizing the V2G scenario. Economic gain can be achieved by using capacity in the EVs in load balancing or voltage control of the charging station. For EV users, the primary incentive for participation lies in economic viability, necessitating appropriate compensation.

Main market actors included in the use case are the CPO, EMME, CEME, EV owner, energy markets and DSO. CEME provides financial compensation for CPO on behalf of the customers and for DSO network access costs. DSO offers EV users remuneration to charging electric bill for participation to the V2G services. EV user pays in the charging electric bill part for each CEME, CPO and EMME that is determined charging time, power consumed or a fixed rate per charging session.

For efficient operation of the use case connectivity among multiple market actors is required. EMME plays a pivotal role in ensuring communication between CPO and EMSP and compatibility with regulatory framework. It aims to achieve seamless operation of services in V2G system and ensure interoperable flow of information and payments. Meanwhile CPO communicates the charging information to DSO ensuring available flexibility.

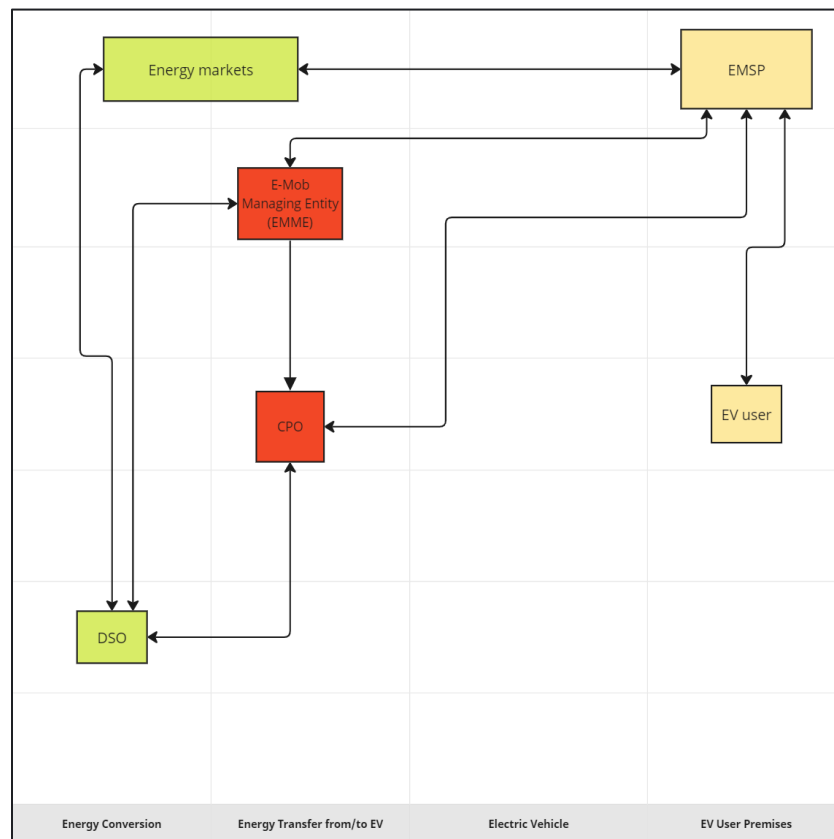


Figure 29 - EMSA Business layer for fork UC4.2 - Maia V2G testing and validation.

Functions related to UC4.2 are showcased in the EMSA function layer shown in figure 30. These functions include charging slot management, grid management, energy management that contains load balancing and voltage regulation, CS management, smart EV charging control, metering, EV management and EV user services.

EMSA component layer for UC4.2 is demonstrated in figure 31. The components layer holds the relevant components of this UC. The energy market system manages energy market operations. The EMME system upholds the e-mobility network system. EMSP system operates the smart charging session web app and communicates with CS operator system about charging session. CS operator system communicates with CS management system. CS management system operates the CS controller that in turn gives commands to EVSE controller. EV system includes EV charging controller, battery management system and sensors and controllers which together upkeep the EV operations. The energy market system is in contact with grid management system which supplies CS EMS and gains information from measurement devices inspecting grid state. Smart charging session web app is connected to EV user via ad hoc UI.

The information layer for UC4.2 is presented in figure 32. It has information protocols OCPI, OCPP, REST, IEC61850, IEC62196-3 and IEC15118. REST defines standard for information exchange between energy market systems and grid management systems or EMSP. It is also used for determining communication between web application and user interface. OCPI protocol is used in enterprise and market level for information transfer between EMME system, CS operator system and EMSP system.

The information layer for UC4.2 is presented in figure 32. It has information protocols OCPI, OCPP, REST, IEC61850, IEC62196-3 and IEC15118. In management of charging operations OCPP protocol is used. The IEC 61850 standard ensures interoperability in grid management and measuring interfaces. IEC 62196-3 and IEC 15118 define features for connector and vehicle for V2G capability. REST is used as a standard in network operations included in user interface and energy markets network interfaces.

EMSA communication layer for UC4.2 is introduced in figure 33. The communicational protocols included are TCP, UDP and HTTPS. TCP or UDP is utilized mostly in communication across components.

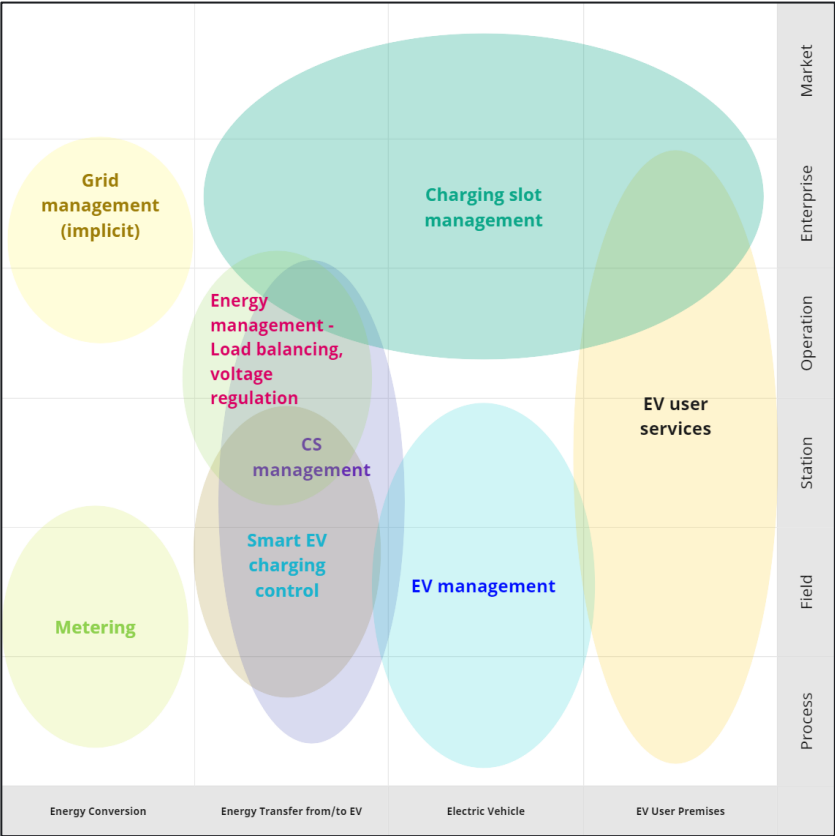


Figure 30- EMSA Function layer for fork UC4.2 - Maia V2G testing and validation.

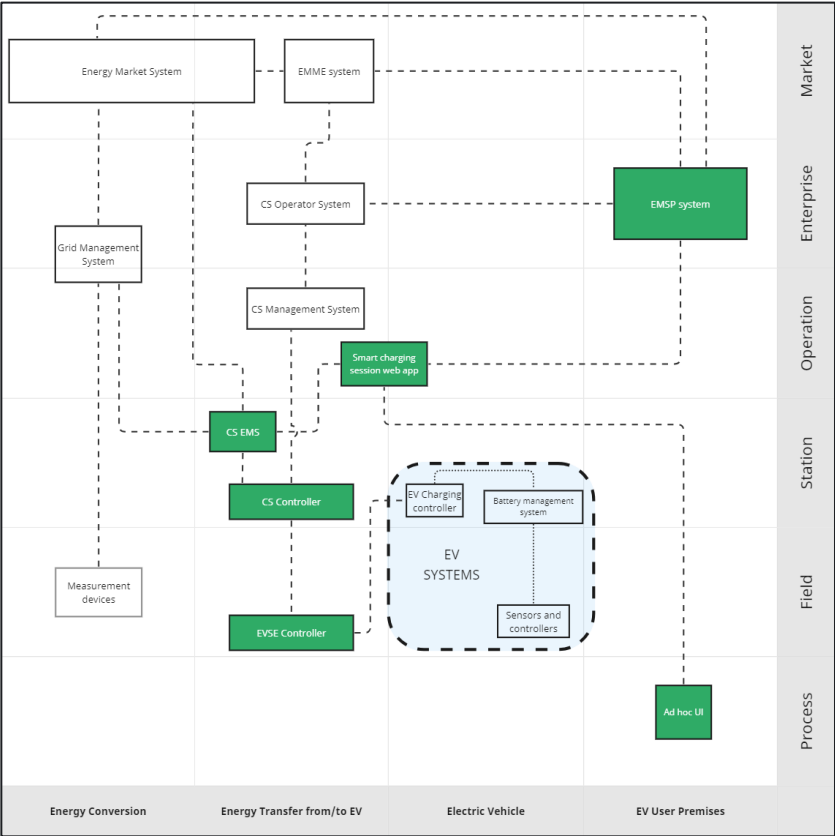


Figure 31- EMSA Component layer for fork UC4.2 – Maia V2G testing and validation.

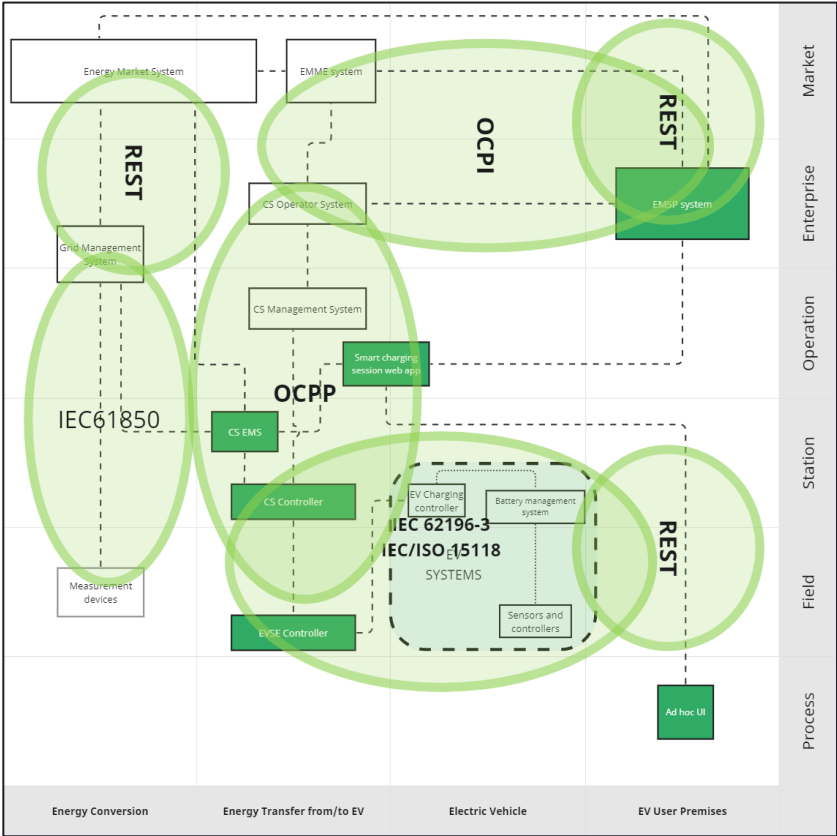


Figure 32- EMSA Information layer for fork UC4.2 - Maia V2G testing and validation.

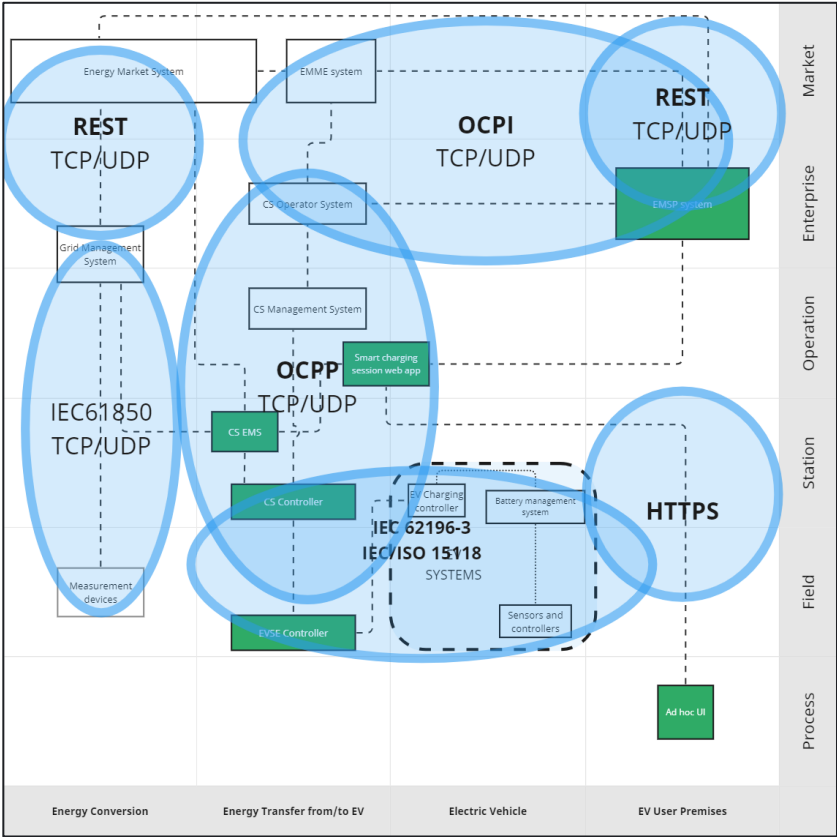


Figure 33 - EMSA Communication layer for fork UC4.2 - Maia V2G testing and validation.

3.4.2.2 Integrated characterization of requirements

A use case is a powerful tool that allows us to understand how users interact with a system or product. It provides a structured way to describe in detail how systems and devices interact and what is user's role in the UC. The following detailed description summarizes the core element of the fork UC4.1 in Table 24. The fork UC4.1 is further developed into stepwise depiction of exchanged information and component use for realization in Table 25. In essence, this depiction captures the conversation between different component involved in the UC.

Table 24 - Detailed framing for fork UC4.2 Vehicle-to-grid integration in public charging stations for addressing technical grid constraints - Maia V2G testing and validation.

Primary actor	EV user
Goal of primary actor	1. Charging of EV, with designated SOC at disconnection time to ensure mobility needs. 2. Offset EV upfront costs by capturing additional revenue streams from V2G services.
Main UC success scenario (User story, primary actor)	Marcos drives his EV to the e-hub charging station and plugs it into the charger, triggering a bi-directional charging event using ad-hoc user interface. During the smart charging event, the car's battery together with the charging equipment contributes to local energy balance in harmony with other possible energy resources such as smart chargers in the same LV network. When the charging event is terminated, Marcos' car's battery is at full charge or at the predefined target SoC to ensure the least disruptive operation possible of the car and that mobility goals are reached. Marcos drives away from the e-hub.
Linked business model	BM1- Flexibility services offered by EV owners or prosumers to network operators BM6 - Distribution network management through procurement of local V2X flexibility

Table 25 - Stepwise depiction of exchanged information and component use for realization of fork UC4.2 - Maia V2G testing and validation.

Step	Action	Linked information exchange	Linked component's use
1	EV driver arrives to the parking area	N.A.	N.A.
2	EV driver plugs car in to the bi-directional charger to begin charging event	ISO15118-20 information of the plug-in even	EV charger controller, EVSE controller
3	EV driver interacts with ad-hoc UI	Session creation	Ad-hoc UI, Smart charging session webapp
4	EV driver opts for bi-directional charging and accepts GDPR notice (registers if not already registered)	Consent for data processing and registration details	Ad hoc UI, Smart charging session web app, potentially EMSP system for registration
5	EV driver sets estimated departure time and preferred SOC at the time of the departure.	Desired state of charge (SOC) and departure time	Ad hoc UI, Smart charging session web app
6	The EV driver starts charging event using UI	Command to start the charging session	Ad hoc UI, Smart charging session web app, CS EMS

Step	Action	Linked information exchange	Linked component's use
7	UI backend processes request and sends start signal to CS EMS while also informing EMSP of the charging session (delivers energy accumulation for billing activities)	signal for charging, energy usage data for billing	Smart charging session web app, CS EMS, EMSP system
8	CS EMS sends start signal to downstream via OCPP framework to CS controller which creates charging session and triggers start signal to EVSE controller.	signal for charging session, session details	CS EMS, CS Controller, EVSE Controller
9	EVSE controller initializes session with the vehicle and subscribes real-time data streams according to ISO15118-20.	Real-time data stream subscription, session initialization	EVSE Controller, EV Systems
10	CS EMS begins load balancing service to optimize grid usage in the station. CS EMS acquires data to support optimization.	Load balancing data, optimization commands	CS EMS, Grid Management System
11	Event is stopped via user input to the EV charging control system, and communicates session termination to the EVSE controller, which subsequently informs CS EMS, and smart charging session web app. Alternatively, we charging event can be stopped via ad-hoc mobile app.	Stop signal for charging session, session termination data	Ad hoc UI or mobile app, EVSE Controller, CS EMS, Smart charging session web app
12	EV charging web app summarizes the charging statistics	EV charging statistics	Smart charging session web app
16	EV driver leaves the area	N.A.	N.A.

3.4.3 UC4.3 Terni V2G testing and validation environment

In Terni city, Drive2X will produce a large-scale demonstration of a sophisticated E-mobility market featuring both V2G and smart charging operations in an integrated urban EV charging infrastructure. The demo will take place on Terni's distribution grid and seeks to ameliorate its stability by means of integrating smart bidirectional EV charging, the objective being to minimize the congestion of the grid due to the increasing penetration of renewable energy. Every year, the Terni distribution network supplies approximately 400 GWh to their circa 65 000 customers but suffers from reverse power flows from prosumer generation that is not self-absorbed and needs to be fed back into the grid, which can amount to 25 GWh. Expansion of smart charging in the city is thus seen as an opportunity to absorb these flows and minimize the current need for recurring TSO balancing, especially during the summer.

Currently, there are 50+ EV chargers scattered around the city managed by different CPOs and EMSPs. However, ASM Terni has determined that the hosting capacity of the power distribution network in the city allows the installation of additional equipment targeting the E-mobility. Thus, the local municipality plans to soon increase this number to about 100 units. This has created the opportunity to realize this demo, in the sense that the installation of V2G stations can improve the stability of the grid in some areas of the city.

The demonstrator will engage and work with varied E-mobility players already present in Terni city. Umbria Energy, a CPO and EMSP that is a subsidiary of ASM, will be engaged to manage the charging infrastructure and partner with Drive2X partners, especially EMOT for integration of V2G services into one or more charging stations to be selected. In principle, smart charging services will be accessible through the EMSP interface

and backend, but V2G session access may need to be integrated via in-house UI/web app as it has been proposed for other Drive2X demos. EMOT also plans to test the roaming functionality of their platform in this demo. EV users will be recruited to participate in the demonstrator by engaging a local EV users' community, but the availability of EVs and their compatibility with V2G services has not yet been determined.

Being the distribution network of Terni city ASM's territory, there is an opportunity to test the contribution of distributed V2G services to the balancing and stability of the grid, which this demo will capitalize on. The Drive2X consortium, in particular ENG, will thus provide an aggregated flexibility marketplace for decentralized grid congestion relief services, which will be blockchain-based and reliant on tokenization mechanisms for data security and privacy. A clearing house for these E-mobility services will also be implemented, handling near real-time transaction settlements and interoperability of different payment systems/roaming.

3.4.3.1 Mapping of market and technical requirements

The Terni city center demonstrator explores the V2G and smart charging operations creating an urbane e-mobility market infrastructure in which efficient exchange of flexibility and grid services can be achieved. The objective for this demonstrator is to minimize grid congestion with V2G technology and promote increasing renewable energy integration.

EMSP will provide EV users with the charging user interface enabling access to V2G services. It is also responsible for billing EV users for energy supply and CPO services and providing remuneration for V2G services delivered to DSO. Clearing house facilitates near real-time transaction settlements and ensures interoperability among various payment systems and roaming services for EMSP.

CPO has information exchange with EMSP about available flexibility capacity and charging information. CPO collaborates with DSO regarding charging station design so that efficient exchange of resources and electricity infrastructure can be achieved.

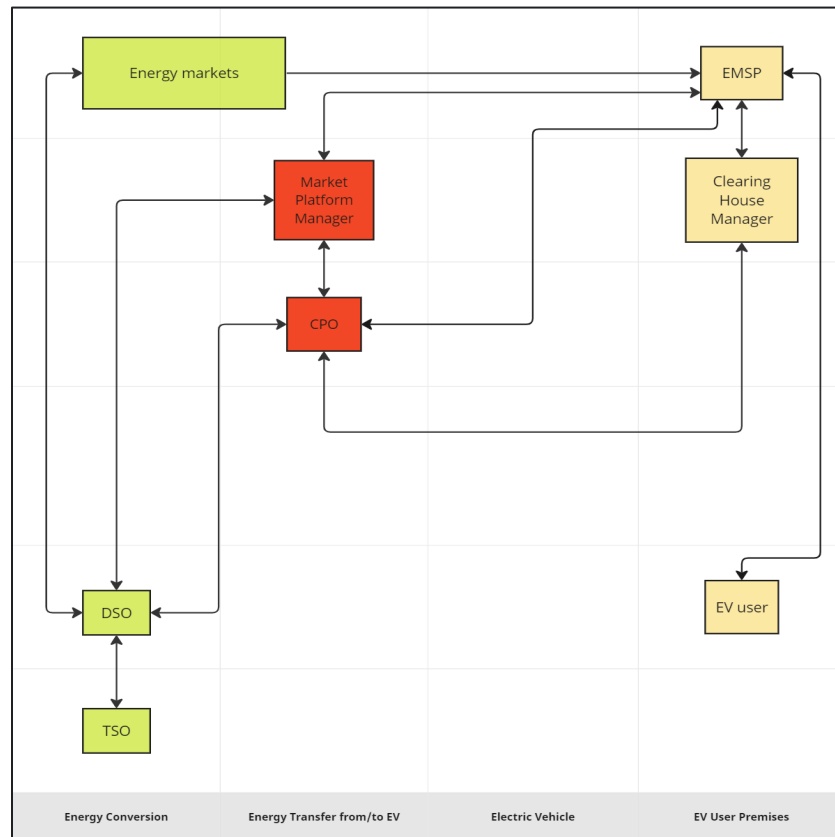


Figure 34 - EMSA Business layer for fork UC4.3 - Terni V2G testing and validation.

Technical requirements for UC4.3 include defining of relevant functions, components, interfaces for information exchange and communication protocols. EMSA layer in figure 35 defines the functions related to this UC; grid management, energy management, charging slot management, EV user services, EV management, smart EV charging control, CS management and metering.

EMSA component layer withholds the main components of UC4.3 and their connections. This is presented in figure 36.

The local flexibility market platform operates flexibility resources such as DERs, energy storages and local loads for the benefit of system operator. It is in contact with DSO dashboard and EMSP system for handling of flexibility resources EMSP system offers.

Clearing house enables efficient communication between EMSP system and CS operator system. CS operator system communicates with CS management system that in turn communicates with CS controller. CS controller gives commands to EVSE controller which communicates with EV systems; EV charging controller, battery management system, sensors and controller.

CS EMS is connected to energy market system and grid management system as CS EMS ensures energy buying and supplement to charging station. Grid measurement devices are in contact with forecast service and grid management system. CS EMS is in contract with CS controller for determining charging actions.

EMSP system accomplishes energy trading of EV flexibility and is linked to energy market system and CS EMS. It monitors charging and EV system for achieving real-time assessment of battery capacity. Through

application and EV user interfaces EMSP system communicates with EV owner and gains knowledge of customer preferences and payment.

EMSA information layer for UC4.3 is given in figure 37. It has information protocols defining information exchange such as Rest API, OCPP, MQTT, IEC62196-3 and IEC15118. The rest API is used in network information exchange among EMSP system, clearing house, LFMP, energy market system and DSO dashboard. It is used respectively in information exchange between web app and user interface. MQTT is used in information exchange between sensors and EMSP system or grid management system. OCPP is again used in charging management and IEC standards in standardization of V2G features in connectors and vehicles.

The EMSA communication layer for UC4.3 is available in figure 38. Relevant communication protocols for UC4.3 include HTTPS, TCP/IP, UDP, IEC62196-3 and IEC/ISO 15118.

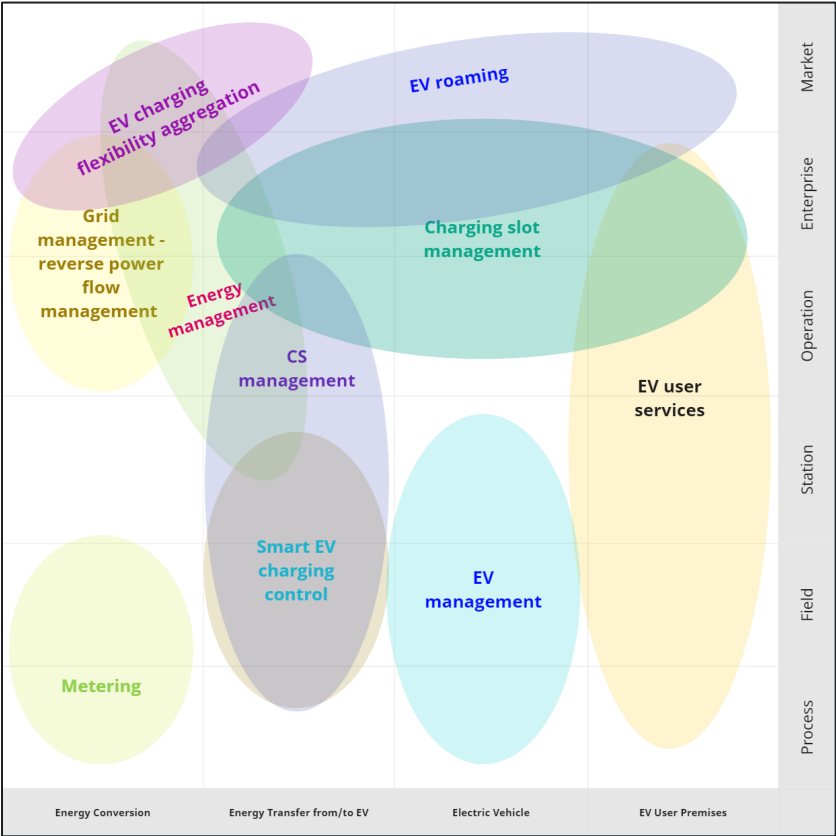


Figure 35 - EMSA Function layer for fork UC4.3 - Terni V2G testing and validation.

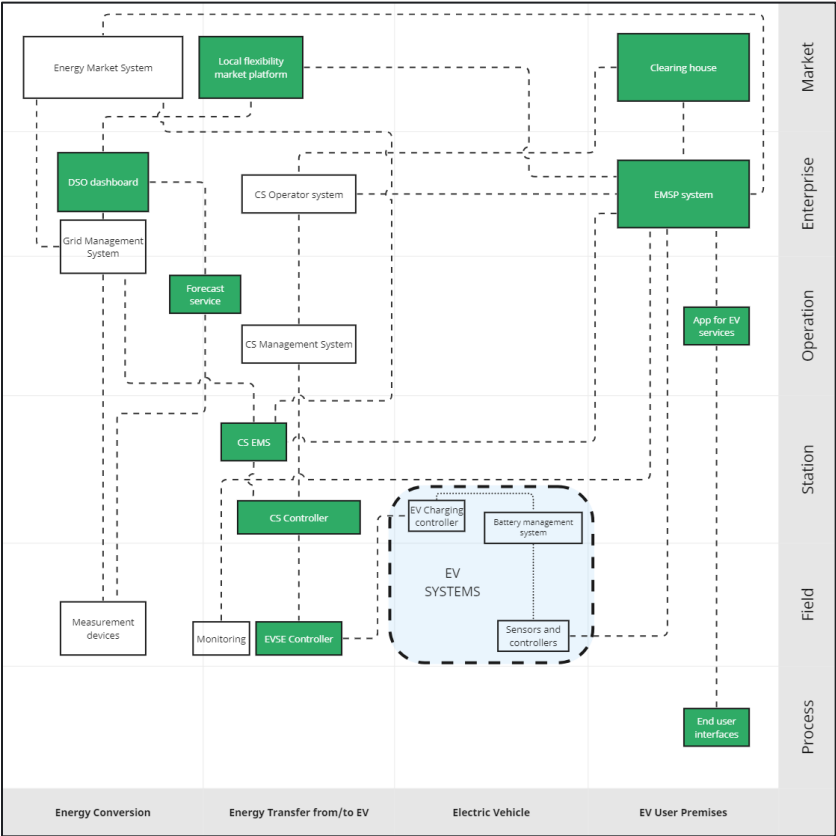


Figure 36 - EMSA Component layer for fork UC4.3 - Terni V2G testing and validation.

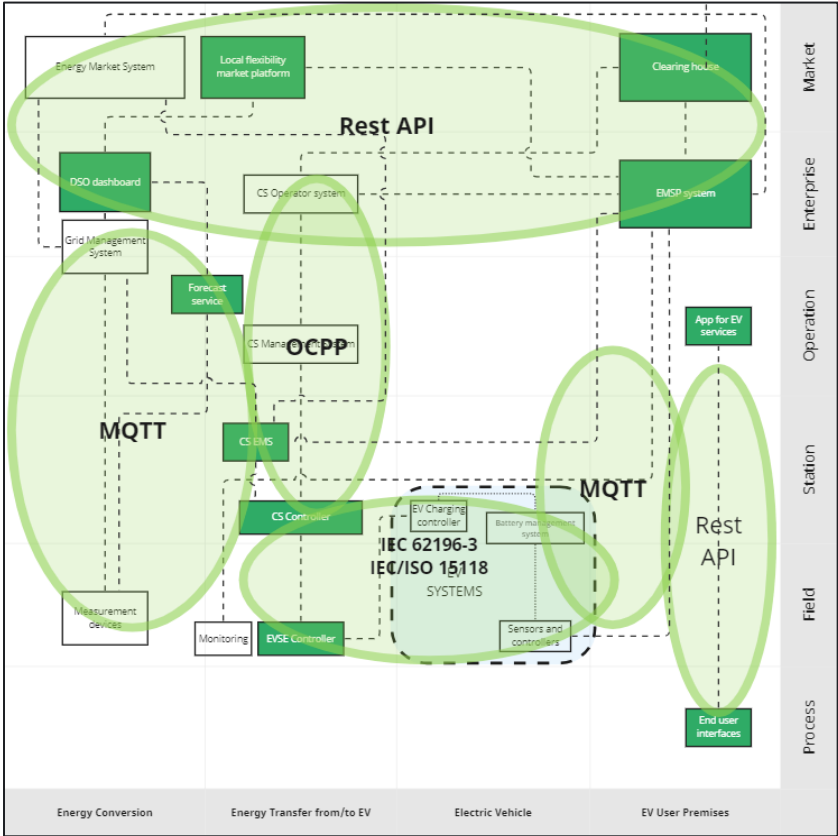


Figure 37 - EMSA Information layer for fork UC4.3 - Terni V2G testing and validation.

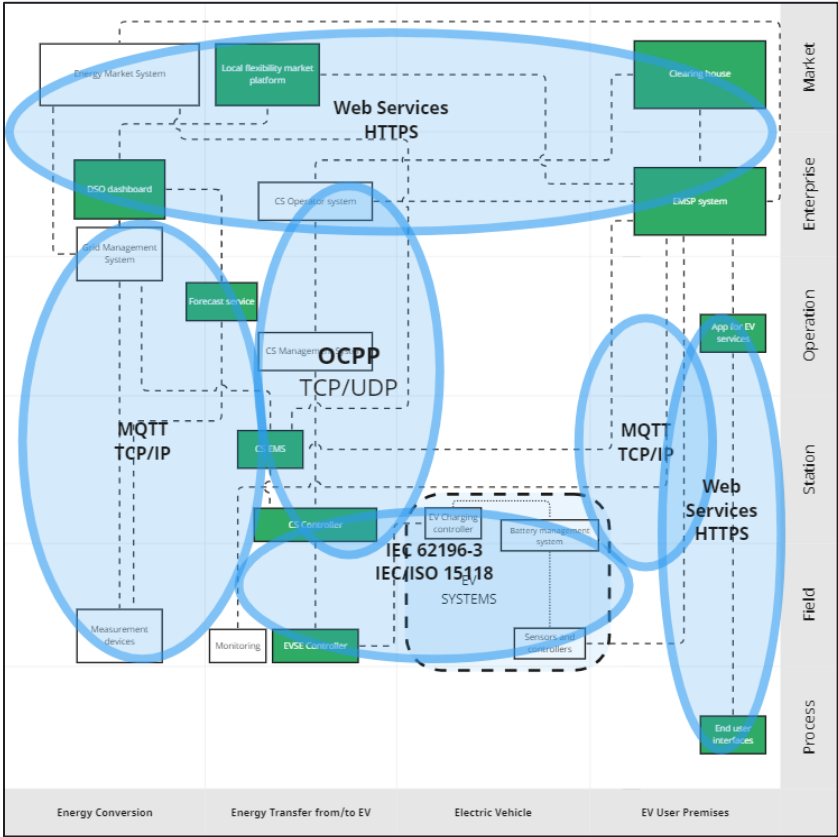


Figure 38 - EMSA Communication layer for fork UC4.3 - Terni V2G testing and validation.

3.4.3.2 Integrated characterization of requirements

A use case is a powerful tool that allows us to understand how users interact with a system or product. It provides a structured way to describe in detail how systems and devices interact and what is user's role in the UC. The following detailed description summarizes the core element of the fork UC4.1 in Table 26. The fork UC4.1 is further developed into stepwise depiction of exchanged information and component use for realization in Table 27. In essence, this depiction captures the conversation between different component involved in the UC.

Table 26 - Detailed framing for fork UC4.3 Vehicle-to-grid integration in public charging stations for addressing technical grid constraints - Terni V2G testing and validation.

Primary actor	EV user
Goal of primary actor	1. Charging of EV, with designated SOC at disconnection time to ensure mobility needs. 2. Offset EV upfront costs by capturing additional revenue streams from V2G services.
Main UC success scenario (User story, primary actor)	Alessandro uses an EMSP UI to identify an available charging point. He drives his EV to that public charging station and plugs it into the charger. The UI invites Alessandro to participate in a DSO flexibility campaign, which suggests that revenues from V2G services could be attained. He accepts to do so, triggering a bi-directional charging session. During the smart charging event, the car's battery through the charging equipment offers demand/supply balancing to the distribution grid, with various charging/discharging cycles. When the charging event is terminated, Alessandro's car's battery is at full charge or at the predefined target SoC to ensure the least disruptive operation possible of the car and that mobility goals are reached. Alessandro is notified by the EMSP UI of how much revenue he made from V2G services. He then drives off from the charging station.
Linked business model	BM1 - Flexibility services offered by EV owners or prosumers to network operators BM6 - Distribution network management through procurement of local V2X flexibility

Table 27 - Stepwise depiction of exchanged information and component use for realization of fork UC4.3 - Terni V2G testing and validation.

Step	Action	Linked information exchange	Linked component's use
1	EV driver arrives to the parking area	N.A.	N.A.
2	EV driver plugs car in to the bi-directional charger to begin charging event	ISO15118-20 information of the plug-in even	EV charger controller, EVSE controller
3	EV driver interacts with EMSP UI	Session creation	EMSP UI, Smart charging session webapp

4	EV driver opts for bi-directional charging and DSO flexibility campaign and accepts GDPR notice (registers if not already registered)	Consent for data processing and registration details	EMSP UI, Smart charging session web app, potentially EMSP system for registration
5	EV driver sets estimated departure time and preferred SOC at the time of the departure.	Desired state of charge (SOC) and departure time	EMSP UI, Smart charging session web app
6	The EV driver starts charging event using EMSP UI (or event starts automatically after required data is inputted and campaign is approved)	Command to start the charging session	EMSP UI, Smart charging session web app, CS EMS
7	EMSP processes request and sends start signal to CS controller while also informing also starting to interact with flexibility marker (Table 28)	signal for charging, energy usage data for billing	EMSP, CS controller, Local flexibility market platform
8	CS controller sends start signal to EVSE controller.	signal for charging session, session details	CS Controller, EVSE Controller
9	EVSE controller initializes session with the vehicle and subscribes real-time data streams according to ISO15118-20.	Real-time data stream subscription, session initialization	EVSE Controller, EV Systems
10	EMSP continues interacting with the local flexibility market (Table 28 and Table 29). EMSP triggers CS setpoint commands accordingly.	Bidding information, flexibility offers, CS controller setpoints	CS controller, Local flexibility market platform, EMSP
11	Event is stopped via user input to the EV charging control system, and communicates session termination to the EVSE controller, which subsequently informs CS EMS, and smart charging session web app. Alternatively, the charging event can be stopped via ad-hoc mobile app. Stop signal triggers final settlement of the session (Table 30).	Stop signal for charging session, session termination data	EMSP UI, EVSE Controller, CS EMS, Smart charging session web app
12	EV charging web app summarizes the charging statistics and informs EV driver of the statistics and payments.	Charging statistics and payment statistics or information	Smart charging session web app
16	EV driver leaves the area	N.A.	N.A.

Table 28 - User accepts to participate in the DSO flexibility campaign.

Step	Action	Linked information exchange	Linked components' use
1	User gets list of DSO requests	List flexibility requests	EMSP system UI
2	User sets preferences (price, minimum state of charge of EV)	User preferences	EMSP system UI
3	User requests to participate in a specific DSO flexibility campaign	Flexibility offer	EMSP system UI
4	The EMSP system puts flexibility offer in the marketplace	Flexibility offer	Marketplace

5	User gets confirmation	Flexibility offer	EMSP system UI
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Table 29 - Requests and offers matching.

Step	Action	Linked information exchange	Linked components' use
1	The market session closes	N.A.	Local Flexibility Market Platform
2	The Marketplace gets the list of bids	Bids information	Local Flexibility Market Platform
3	The Marketplace determines the best bid in order to better respond to DSO's request	Bids information	Local Flexibility Market Platform

Table 30 - Verification and payment settlement.

Step	Action	Linked information exchange	Linked components' use
1	Real-time charging data provided by the EVSE is properly retrieved	Charging data	CPO system
2	The DSO unlocks payment for the flexibility request	Payment transaction	EMSP system
3	The EV owner gets the incentives for flexibility offered	Payment transaction	EMSP system
4	The EMSP gets economic benefits for providing service	Payment transaction	EMSP system

3.5 UC5 Vehicle-to-grid for network stabilization of locally-managed RES congested grids

The unique ASM Terni microgrid V2G demonstrator will study the role of smart bidirectional EV charging in supporting the stability of small distribution networks with localized control, by balancing load demand and generation during the operation in both AC and DC modes.

The demo will deploy two 22 kW smart V2G chargers in a charging station located in the premises of ASM Terni's headquarters "Living lab" facility, whose site configures a hybrid AC/DC microgrid enriched with various demand loads and DER. The existing charging stations already count with several unidirectional EV chargers. The facility counts with 240 kW of PV power, a second-life battery storage of 66 kWh/72 kW, and a biodiesel-fed generator to support operation during islanding events. For experimental purposes, part of this microgrid is fed in DC, and this branch will host an additional 50kW fast EV charger. In terms of building demand, the facility includes an office building and warehouse that draw 150 kWp and is equipped with an

EMS for efficiently and remotely managing HVAC loads. The entire network and energy units are monitored by an Advanced Metering Infrastructure (AMI) providing real-time and historical data outputs.

The participants will be recruited from ASM's staff. They will be using a fleet of 10 EVs that will be sourced by EMOT for the purpose of the demonstrator. Office hours use of the chargers is expected to retrieve several short to medium duration charging/discharging sessions per day and provide valuable learning opportunities on the grid balancing element of diurnal V2G and its ability to enhance renewable uptake at distribution level.

In this demo, the role of each player has been defined early on. ASM Terni is the DSO and will also operate as "local energy manager", running the logic programmed in the microgrid controller (i.e., the optimized control decisions of the microgrid). This management entity operates as an aggregator of the local resources (including of the charging station's flexibility...) performing dynamic balancing of supply and demand within the boundaries of the microgrid and ensuring that its energy demands are met sustainably and efficiently. Given the extensive AMI in place, ASM Terni will be able to carefully assess and compare the behavior of the grid both with and without V2G integration, as well as perform various smart charging experiments with respective technical performances' data logging. EMOT will provide the EV fleet and the two 22 kW V2G chargers, as well as the additional 50kW fast EV charger. They will also operate as the CPO entity running the charging facilities. With support from the Drive2X partners, EMOT will thus lead the development and implementation of charging station management solutions compatible with V2G, as well as the web app and UI for managing individual charging/discharging sessions. It will also liaise with the DESO to ensure the availability of charging capacity and to manage the scheduling of EV charging sessions. Electricity for EV charging in the premises will be provided through ASM Terni's TOU supply contract. The possibility of offering rewards for the V2G participants has not yet been discussed for this demo.

Table 31 - General framing for UC5 Vehicle-to-grid for network stabilization of locally-managed RES congested grids.

Use case coding	UC5
Use Case name	Vehicle-to-grid for network stabilization of locally managed RES congested grids
Technical actors (function-based categorization)	DSO, EMSP, Fleet Operator, EV User, Market Platform Manager, Local Energy Manager, EV user, and Energy Markets, including different types of actors
Prerequisites	- DSO and EMSP are registered in the marketplace. - EVs belong to one fleet
Linked demo	Demo 8 - ASM Terni microgrid (V2G)
Linked business models	BM1 - Flexibility services offered by EV owners or prosumers to network operators BM6 - Distribution network management through procurement of local V2X flexibility (DSO)

3.5.1 Mapping of market and technical requirements

In this distinctive UC, a fleet manager operator will be the key market actor addition to other UCs. The ASM Terni microgrid V2G demo will demonstrate the enhanced management of energy flexibility in distribution networks with localized control and multiple DER assets by integrating short to medium-term, office hours' bidirectional charging of EV fleets. The EMSA's business layer representation for this demo is depicted in Figure 39 which showcases the business interaction in the microgrid environment. The business interactions illustrate how EV battery as a flexibility resource becomes an integral part of the microgrid operation.

Technical requirements for UC5 are represented in this section from the perspective of functions, components, information and communication and mapping of EMSA layers for each of them is conducted. Figure 40 illustrates the interrelated functions that together enable the efficient operation of the V2G system in the microgrid, i.e., it shows the EMSA's function layer for this demo. The functions work together to form a cohesive system that supports the Terni microgrid's operational goals, ensuring that the integration of V2G technology enhances grid stability, energy efficiency, and the use of renewable energy sources.

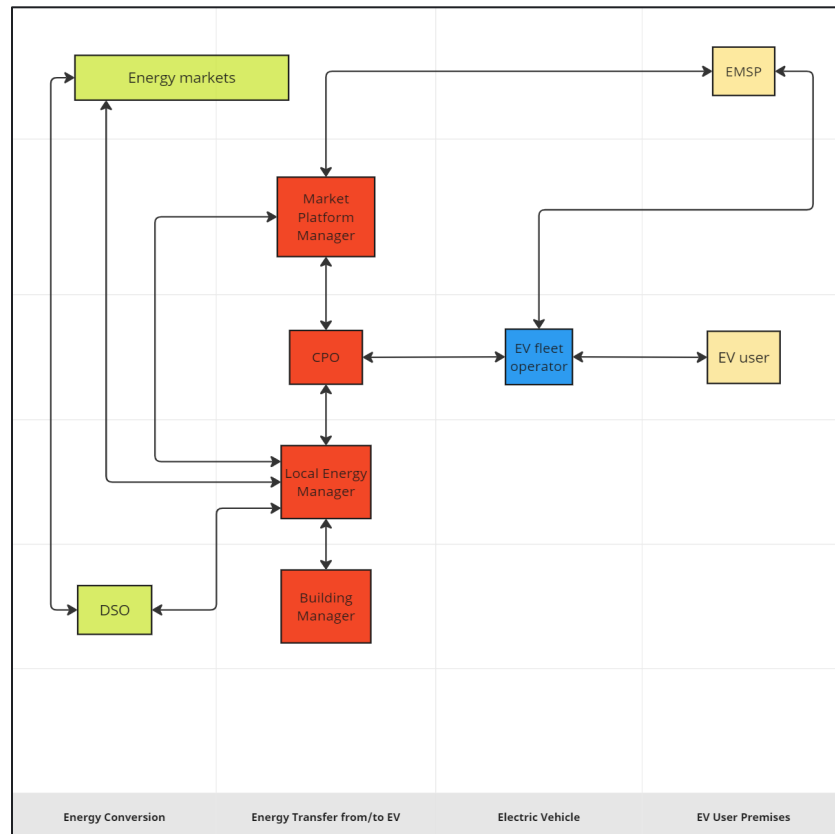


Figure 39 - EMSA Business layer for UC5 - Terni microgrid testing and validation.

Essential functions for UC5 include e-mobility data trading, charging slot management, EV fleet management, energy management, MG management including load balancing in AC and DC modes, CS management, EV user services, EV management, EV charging flexibility aggregation, building automation, metering and smart EV charging control. The EMSA function layer found in figure 40 maps these functions to domains and zones.

Main components of UC5 are mapped in EMSA component layer in figure 41. LFMP navigates flexibility resources and receives offers from EMSP system and requests from MG balancing dashboard. MG balancing dashboard receives information from hybrid AC/DC control system and forecast service which both gain information from sensors and measurement. Hybrid AC/DC control system gets information from BEMS and CS EMS. CS EMS controls the CS controller which in turn controls the EVSE controller that supplies EV and gains information from EV systems. CS controller is also managed by CS management system which is operated by CS operator system. Energy market system operates energy markets in which EMSP system and hybrid AC/DC control system trade energy. EMSP system is communicating CS EMS and fleet management system about charging requests. EMSP system receives information from monitoring about charging. It also

contacts the app for EV services about charging and the app user interface. Fleet management system gains information from EV systems sensors about charging.

The EMSA information layer for UC5 is presented in figure 42. The relevant information protocols included in this UC are Rest API, OCPP, MQTT, IEC62196-3 and IEC15118. Essential communication protocols are mapped in EMSA communication layer found in figure 43. These include HTTPS, TCP/IP, IEC62196-3 and IEC15118.

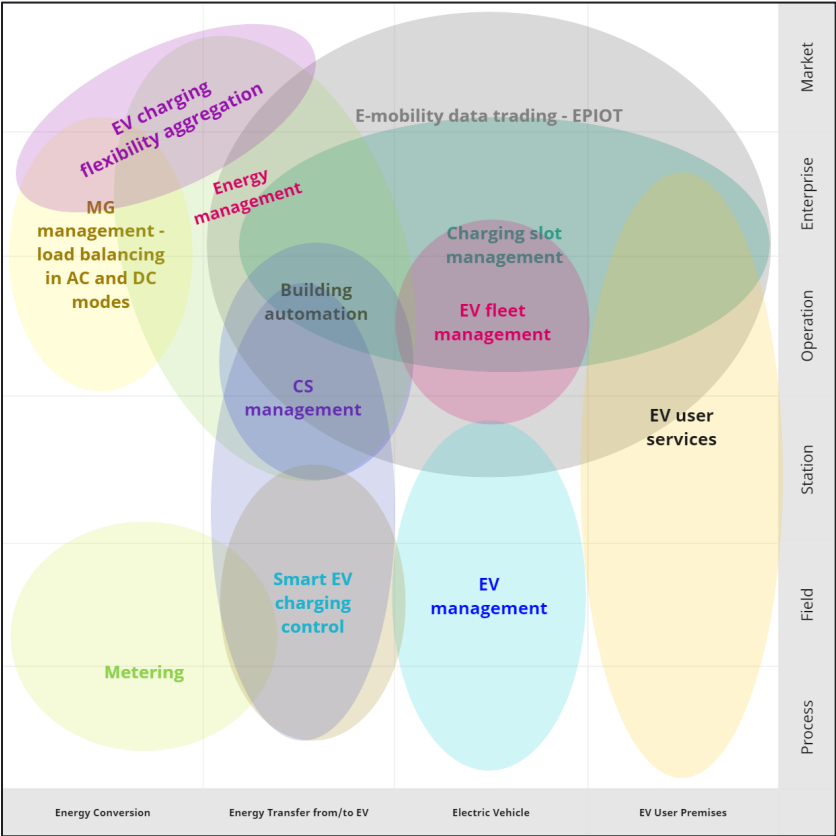


Figure 40 - EMSA Function layer for UC5 - Terni microgrid testing and validation.

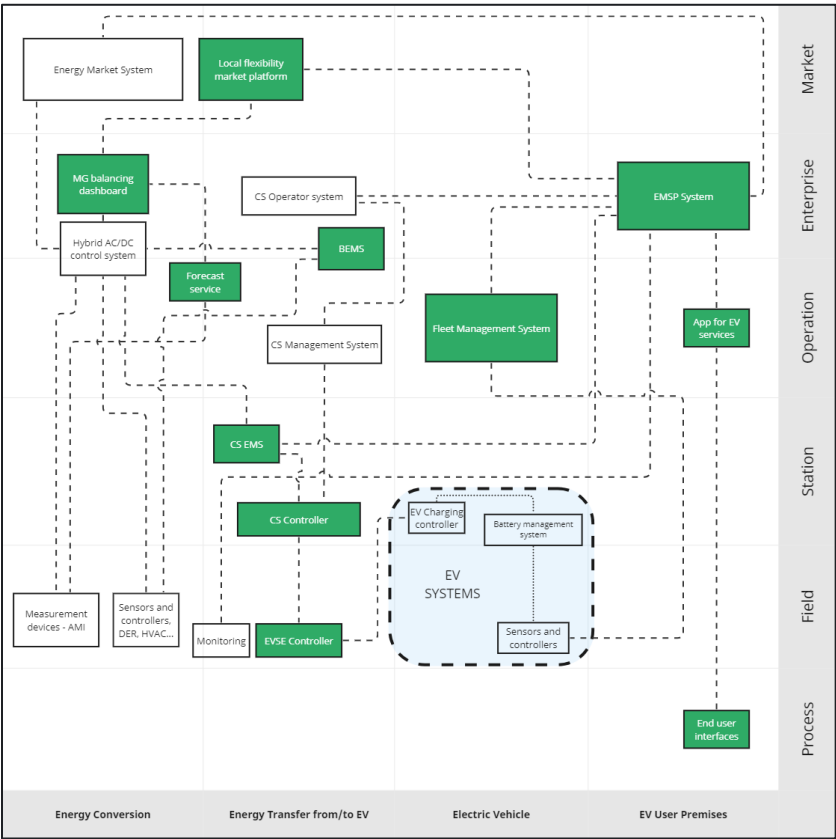


Figure 41 - EMSA Component layer for UC5 - Terni microgrid testing and validation.

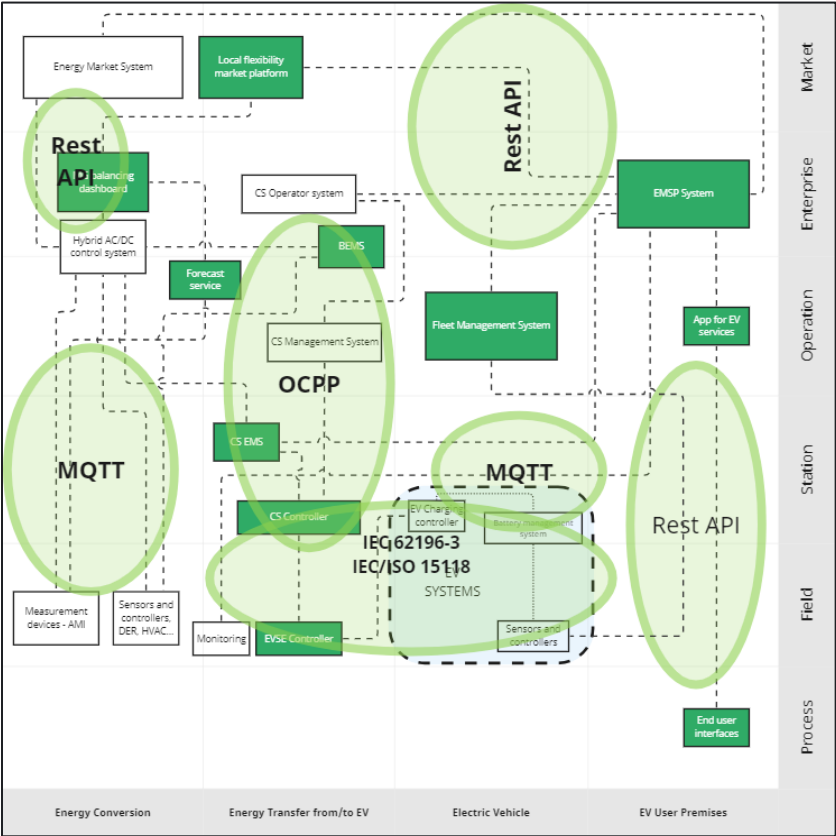


Figure 42 - EMSA Information layer for UC5 - Terni microgrid testing and validation.

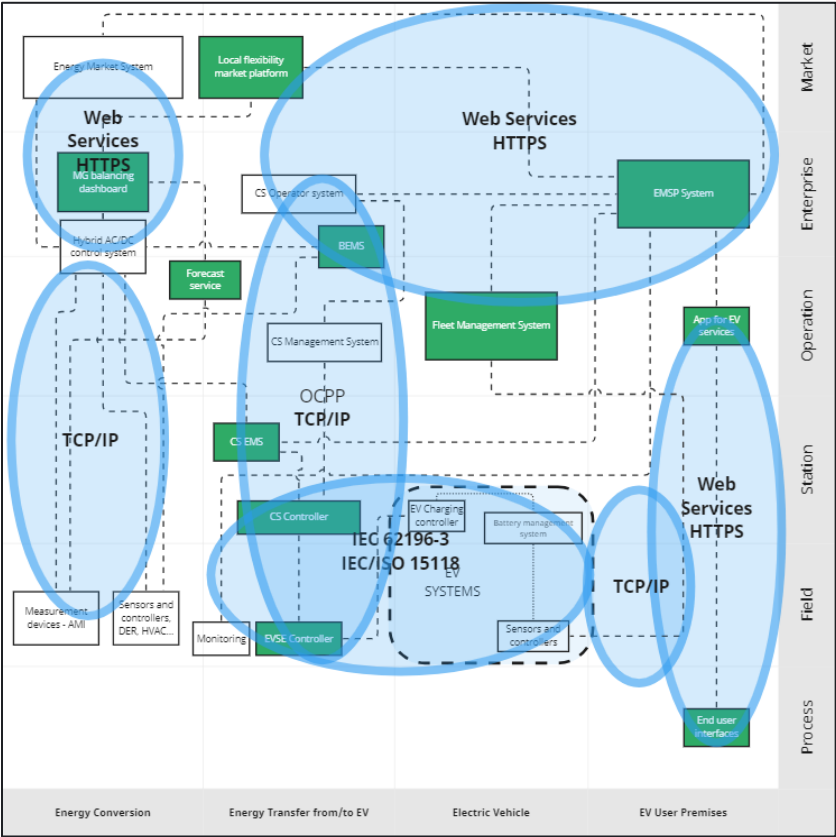


Figure 43 - EMSA Communication layer for UC5 - Terni microgrid testing and validation.

3.5.2 Integrated characterization of requirements

A use case is a powerful tool that allows us to understand how users interact with a system or product. It provides a structured way to describe in detail how systems and devices interact and what is user's role in the UC. The following detailed description summarizes the core element of the UC5 in Table 32. The UC5 is further developed into stepwise depiction of exchanged information and component use for realization in Table 33. In essence, this depiction captures the conversation between different component involved in the UC.

Table 32 - Detailed framing for UC5 Vehicle-to-grid for network stabilization of locally-managed RES congested grids.

Primary actor	EV user
Goals of primary actor	• Mobility – As user of a vehicle fleet, the EV user is exclusively concerned about the availability and usability of that vehicle for reaching its mobility goals. The EV user expects the vehicle to be fully charged when disconnected from the charging station
Secondary actor	EV fleet operator
Goals of secondary actor	• Ensuring designated EV battery SOC at disconnection time is reached to ensure mobility needs of EV users. • Offset EV fleet upfront costs by capturing additional revenue streams from V2G services.
Main UC success scenario (User story, primary actor)	Gio requires a vehicle for his daily work duties. He uses the fleet manager's interface to book an EV, and he is informed that the vehicle will be provided at full battery SoC. When he arrives at the station, he is able to disconnect the vehicle from the EV charging point by interacting with the fleet manager UI. Gio drives the vehicle to his destination and returns it to the charging station later in the day, with battery SoC at 35%. Gio leaves the facility. <i><u>Secondary actor's perspective:</u> From the perspective of the fleet manager, the main complexity in this UC consists in trading off revenues from EV user bookings with revenues from V2G services. While V2G revenues are beneficial for the financial standing of the management operation, the EVs also need to be available to the EV users. The booking and scheduling system's UI needs to reflect this complexity by imposing limitations/conditions both on fleet use and V2G services.</i>
Linked business model	BM1 - Flexibility services offered by EV owners or prosumers to network operators BM5 - Flexibility services offered by building/facility managers to DSO BM6 - Distribution network management through procurement of local V2X flexibility

Table 33 - Stepwise depiction of exchanged information and component use for realization of UC5 - Vehicle-to-grid for network stabilization of locally-managed renewable energy systems--congested grids testing and validation.

Step	Action	Linked information exchange	Linked components' use
1	EV driver arrives to the parking area and plugs in car for charging.	N.A.	N.A.
2	Car is returned to the fleet management system/scheduling system.	EV user input to fleet manager UI,	Fleet management service,
3	Fleet operator marks car as available.	Fleet management message to UI	
4	The DSO publishes flexibility request in the marketplace (continuous process in background) (Table 34)	DSO input to dashboard/Local flexibility platform	
5	The EMSP system publishes offer bids in the local market platform (Table 35)	EMSP messaging to local flexibility market platform	local market platform, EMSP
6	Requests and offers matching (Table 36)	Matching algorithm taking place inside market platform	local market platform
7	EMSP controls remotely the charging station to accomplish flexibility requested from the DSO (Table 37)	EMSP signal to CS Operator System, who relays to CS Management System, who finally gives instruction to CS controller	EMSP, DSO
8	Next driver books the vehicle through fleet manager and drives away.	(New) EV user input to Fleet manager UI	Fleet manager

Table 34 - The DSO publishes flexibility requests in the marketplace.

Step	Action	Linked information exchange	Linked components' use
1	The DSO calculates building consumption forecasting, PV production forecasting and manage batteries to estimate the amount of energy demand at ASM substation	District forecast	DSO Dashboard
2	DSO realizes there will be a congestion	District forecast	DSO Dashboard
3	DSO submits flexibility request in the marketplace	Flexibility request info (energy, price)	Marketplace

Table 35 - The EMSP system publishes offer bids in the marketplace.

Step	Action	Linked information exchange	Linked components' use
1	Fleet Managers gets list of DSO requests	DSO request	Fleet Manager UI

2	Fleet Manager gets status of fleet EVs and charging stations status	Location, autonomy, energy until full charge of EVs	Fleet Manager UI
3	Fleet Manager calculates EV potential flexibility provision	Forecasting system	Fleet Manager UI
4	Fleet Manager generates the EV charging schedule that addresses the requirements of the DSO	EV charging schedule	Fleet Manager UI
5	Fleet Manager notifies interest of flexibility available to EMSP system	Bid offer information	Fleet Manager UI
6	EMSP system gets list of bids from all Fleet Managers	Bids information	EMSP system UI
7	EMSP system puts bid in the marketplace	Flexibility offer bid	Marketplace

Table 36 - Requests and offers matching.

Step	Action	Linked information exchange	Linked components' use
1	The market session closes	N.A.	Local Flexibility Market Platform
2	The Marketplace gets the list of bids	Bids information	Local Flexibility Market Platform
3	The Marketplace determines the best bid in order to better respond to DSO's request	Bids information	Local Flexibility Market Platform

Table 37 - EMSP controls remotely the charging station to accomplish flexibility requested from the DSO.

Step	Action	Linked information exchange	Linked components' use
1	The EMSP system sends request to charge/discharge EV based on market results	Charge/discharge request	EMSP system
2	The DSO pays for the flexibility request	Payment transaction	Payment system
3	The Fleet Manager gets the incentives for the flexibility offered	Payment transaction	Payment system
4	The EMSP gets economic benefits for providing service	Payment transaction	Payment system

4 Conclusions

The Drive2X project develops new expert knowledge, ICT solutions, and hardware technologies to help cope with a mass V2X-based EV deployment future for Europe. It also investigates the role of behavioral uncertainties in V2X and develops policy tools to support sustained V2X roll-out in European smart cities.

This deliverable provides a comprehensive characterization of the V2X UCs to be tested in the Drive2X project. The description of the UCs focuses on market and technical requirements. The representation is firstly done visually, with help from the EMSA's business, function, component, information, and communication layers, and secondly, by detailed stepwise IEC 62559-2-inspired listing of primary actor steps in realization of the UC, complemented by respective information exchanging and component use.

The above methodology revealed appropriately fitting and detailed, despite the need to continue improving the knowledge on the implementation of the Drive2X UCs.

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