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Impact of mass deployment of V2X in energy markets and services

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Executive Summary

The deliverable *Impact of mass deployment of V2X in energy markets and services* gives an overview of services for the participation of EVs in the energy market, which will be tested and demonstrated in the Slovenian demonstrator as part of the BUC 1 'Participation of Vehicle to Everything in the electricity markets through a virtual power plant' and BUC 6 'Participation of Vehicle to Everything in local Flexibility Markets' described in **D7.1 Detailed definition and implementation plan of Slovenian Demonstrator**. Deliverable D4.4 provides a more in-depth review of the services that were outlined in D7.1. Testing and demonstration of selected services will also serve as an input for the calculation of the KPIs of the Slovenian demonstrator in **D7.4 Analysis of Results.** The selected services presented in this deliverable are crucial for enabling the Electric Vehicles (EVs) participation in the flexibility energy markets.

To better understand the impact of EVs on the energy market, the market and the market platform, which will serve as a central communication hub between the actors in the energy market, will be presented. In addition, an overview of the current state of the Slovenian flexibility market development gives an insight when EVs could participate in this market. Flexibility services that enable the participation of EVs in the energy market are indicated. EV users' perspective on vehicle to Everything (V2X) and their participation in such services, is outlined. A simplified assessment of the impact of EVs on the Slovenian energy market is based on available statistical data.

The market platform, which is being developed as part of the Slovenian demonstrator within the EV4EU project, is outlined in this deliverable. The general idea of the market platform, its integration into the Slovenian demonstrator and benefits are presented. This deliverable gives an overview of the main functionalities of the market platform, the protocols and data formats used in the communication between the market platform and other energy market actors.

The selected services that are going to be tested and demonstrated as part of the Slovenian demonstrator within the EV4EU project are presented. Chosen services are oriented towards TSO, DSO and EV users. The definitions of these services, the benefits they bring as well as their activation and procurement procedures are outlined in this deliverable. The testing and implementation of the services presented in this deliverable fulfils one of the objectives of WP4 *V2X Integration in Smart Grids and Electricity Markets*, which relates to the development of services for the participation of EVs in national and local markets based on the market platform.

The status of the energy market, the timetables, the format in which the flexibility markets will be introduced and the specific aspects of the other three EV4EU demonstrators and their relation to the selected services are presented.

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Keywords, Acronym

aFFR	Automatic Frequency Restoration Reserve
AGEN	Energy Agency in Slovenia
BUC	Business Use Case
CPO	Charge Point Operator
CS	Charging Station
DAM	Day-ahead Market
DSO	Distribution System Operators
EU	European Union
EV	Electric Vehicle
FCR	Frequency Containment Reserve
FFR	Fast Frequency Response
IDM	Intraday Market
IT	Information Technology
mFRR	Manual Frequency Restoration Reserve
MQ	Message Queue
RES	Renewable Energy Sources
REST	Representational State Transfer
SoC	State of Charge
TLS	Traffic Light System
ToU	Time-of-use
TSO	Transmission System Operators
VPP	Virtual Power Plant
V2G	Vehicle-to-Grid
V2X	Vehicle-to-Everything

1 Introduction

Based on the results from **D1.1 Electric Road Mobility Evolution Scenarios** [1] and **D1.2 Impact of V2X in energy and power systems** [2], we can agree that EVs will have a major impact on energy markets in a near future. The present deliverable D4.4 *Impact of mass deployment of V2X in energy markets and services* evaluates the impact of Electric Vehicles (EV) on the energy market when Vehicle-to-Everything (V2X) technology is deployed on a large scale. Potentially, V2X technology can change the role of EVs as a solution provider on the energy markets. In this deliverable, we present selected services for the Slovenian demonstrator that will enable EVs participation on the local and national energy markets.

The European Union's (EU) project EV4EU aims to transform the European EV landscape by introducing user-centric V2X management strategies. These strategies, based on bottom-up approaches, aim to promote the widespread adoption of EVs. This deliverable D4.4 is part of Work package 4 (WP4) *V2X Integration in Smart Grids and Electricity Markets*, which focuses on the integration of V2X in the energy markets and presents foundation for WP7 *V2X Flexibility in Electricity Markets (SI Demo),* the Slovenian demonstrator, in which the selected services will be tested and demonstrated.

The EV4EU project will demonstrate and evaluate the EV participation in national and local energy markets. The focus is on understanding the benefits for EV users participating in markets with V2X and the potential impact of massive V2X engagement. To enable V2X participation in energy markets and services, such as ancillary services and services procured by Distribution System Operators (DSO) or Transmission System Operator (TSO), algorithms have been proposed for use by aggregators, which are presented in **D4.3 Integration of V2X in Charging Point Operators and Virtual Power Plants Aggregation** [3]. These algorithms will facilitate the interaction between V2X technologies and energy markets and will be tested in the Slovenian part of the practical demonstration.

The Slovenian demonstrator will use an extended market platform from the OneNET project [4] to ensure compatibility with national flexibility platforms. The market platform will facilitate the exchange of information between energy market actors and ensure interoperability, scalability, security and privacy.

The impact of a widespread deployment of EVs with V2X capabilities on the energy, ancillary services and flexibility markets will be assessed within EV4EU project. Services will be developed and tested on the market platform that facilitates data exchange between energy market actors. Grid operators will analyse the impact of V2X on the transmission and distribution grid and develop selected services to take advantage of V2X flexibility, counteract the impact and support the growth of V2X and renewables. Developed tools will incorporate these models, although entry into the actual market will depend on an extensive pre-qualification process. If participation in the real market proves unattainable, services will be validated using market simulation tools.

1.1 Scope and Objectives

The deliverable D4.4 *Impact of mass deployment of V2X in energy markets and services* presents an overview of the energy markets, EV user perspective on participation in the flexibility markets and an assessment of the impact that mass deployment of EVs with V2X capability could have on the energy market, the ancillary services market and the flexibility market.

The basic prerequisite for the implementation of the Slovenian demonstrator is the existence of the flexibility market in Slovenia, which is at the beginning of 2024 not yet fully established. The proposed market platform for the Slovenian demonstrator will extend the existing platform developed in the OneNet project [4]. D4.4 collects functionalities of the market platform, communication protocols and data formats used in the exchange of information between actors on the Slovenian energy market.

Furthermore, D4.4 presents selected flexibility services that will be tested and demonstrated in the Slovenian demonstrator. These services focus on the participation of EVs in flexibility markets at local and national levels. A description and review of the activation and procurement procedure of these services in the Slovenian demonstrator is outlined in this deliverable.

1.2 Structure

This deliverable begins with an introduction objectives, structure, and context of deliverable D4.4. With the aim of better understanding the impact of EVs on the energy market, Chapter 2 provides a simplified assessment of the impact that the mass deployment of EVs with V2X capability could have on the Slovenian energy market and beyond.

Chapter 3 describes the market platform that is going to be developed as part of the Slovenian demonstrator. This is followed with the selected flexibility services oriented towards TSO, DSO, EV users, that are going to be demonstrated and tested in the Slovenian demonstrator, collected in Chapter 4.

The status of the flexibility markets and the specific aspects of the other three EV4EU demonstrators and their relation to the services presented in Chapter 4 are analysed in Chapter 5. Finally, Chapter 6 summarises the main points and concludes the deliverable.

1.3 Relationship with other deliverables

The main objective of the task T4.4 was to define services focusing on EV participation in flexibility markets at the local and national levels. The deliverable D4.4 extends the information provided in **D1.4 Business models centred in the V2X value chain** [5], which described the developed Business Models (BMs) that served as the basis for the development of the Business Use Cases (BUCs), documented in **D1.5 V2X Use-cases repository** [6]. Service development takes into account the applicable legal framework in which the project operates, as explored in the legal repository created in Task T1.3 and presented in **D1.3 Regulatory opportunities and barriers for V2X deployment in Europe** [7].

Furthermore, the knowledge on information exchange and communication standards between actors participating in BUCs conduction is summarized from **D5.1 Information Exchange needs to enable different UCs** [8] and **D5.2 Standardisation gap analysis for new V2X related Business Models** [9]. The knowledge on benefits of the market platform is derived from the **D4.2 Scheduling and Real-Time Operation Strategies to Control V2X Flexibilities** [10] and **D4.3 Integration of V2X in Charging Point Operators and Virtual Power Plants Aggregation** [3].

This document serves as an input for **D7.1 Detailed definition and implementation plan of Slovenian Demonstrator** [11]. Services presented in Chapter 4 will be tested in the Slovenian demonstrator using KPIs that are collected in D7.1.

2 Impact of the Electric vehicles on the market

The main objective of the Slovenian demonstrator is to evaluate the participation of EVs through V2X technology in the energy markets. Chapter 2 collects a brief overview of the energy markets: 2.1 provides an overview of the market and the market platform as the central communication hub, 2.2 provides an overview of current developments of the Slovenian flexibility market, 2.3 overviews flexibility services for market participation, 2.4 collects perspective of EV users in relation to V2X based on WP3 activities, and 2.5 assesses the impact of EVs on the Slovenian energy market.

2.1 Market and market platform

The energy markets, consists of national markets, on which the TSOs procure ancillary services such as frequency regulation [12], [13], and the local energy market, a concept that encourages localized services and flexibility trading [14], are undergoing profound change. In contrast to the traditional unidirectional relationship, where end users only purchased electricity from the grid, new technologies are enabling a bidirectional approach, where end users are both consumers and suppliers of energy, creating a more integrated and participatory energy system [15]. This potential was also recognised by the EU, which stipulated for markets to be established or redesigned to take into account the flexibility offered by prosumers (Regulation 2019/943 on the internal market for electricity and Directive 2019/944 on common rules for the internal market for electricity).

A type of energy market is the flexibility market, a market dedicated to the exchange of flexibilities. Which, depending on the type of flexibility traded, can also be local or national [16]. Local flexibilities are traded to solve congestion or voltage related problems. And on national level flexibilities are traded on balancing market, a market for provision of services to TSO, established to solve frequency related problems [17], [18].

On these markets numerous actors can participate, and to facilitate interactions between different actors of the energy markets, market platform, a central communication hub, serves as a connection point between users of flexibility TSOs, DSOs, flexibility providers, Charge Point Operators (CPOs) and aggregators etc. [17].

The local and national flexibility markets are established via the market platform with various functions such as tendering, purchasing, contract conclusion, activation and billing. Such ICT platform facilitates the activation and procurement of flexibility resources for the TSO/DSO through a standardised system. Participation in the balancing markets, which may be integrated into a national flexibility market, requires registration of the flexibility providers. The registration process requires that providers are able to deliver a quantity of flexibility that exceeds a threshold, which is currently 1 MW [19].

The ability of actors to participate in the flexibility market corresponds to flexibility services. These services enable actors to offer their flexibility, activation and its procurement on the market when it is needed. The availability of flexibility services will be crucial in the future, as these services will enable all current and new actors to offer their flexibility on the market [16]. Selected services that are going to be implemented in the Slovenian demonstrator and will enable the participation of EVs in the market are outlined in Chapter 4.

Important technology which has a potential for flexibility is V2X, or more precisely Vehicle-to-Grid (V2G). In essence this technology supports bidirectional energy exchange and communication between the vehicle, in our case the EVs, and the energy grid [20], [21], [22].

Given the increasing number of EVs, which are also presented in [1], EVs can pose a serious problem for the energy grid if they are managed just as a normal consumer. By also allowing discharging, we turn EVs into active providers of solutions for the energy markets. This topic was also the subject of research in this project and was presented in [2]. For these reasons, EVs can be a valuable actor in the provision of flexibility.

2.2 Development of Slovenian Flexibility market

The above-mentioned EU regulation and directive are incorporated into the Slovenian regulatory framework by the Zakon o oskrbi z električno energijo. As outlined in [7], [5], the basic elements for flexibility trading lie in Articles 75 and 79. Nevertheless, a national market as well as local market are still under development.

The Energy Agency in Slovenia (AGEN) is actively involved in the development of the Slovenian flexibility market. AGEN is working on creating a regulatory framework, developing a strategy for the integration of the local flexibility market, compiling a list of services for the flexibility market and designing the architecture for its integration with the current energy market [23].

Currently, the flexibility services available in Slovenia are limited to the balancing market, where flexibility providers can participate in the Manual Frequency Restoration Reserve (mFRR). The current state of the flexibility market in Slovenia is characterised by pilot projects and studies on the integration of new flexibility markets and platforms with existing energy markets [24]. Participation in the flexibility market in Slovenia is limited to companies involved in various pilot projects such as X-FLEX [25].

The integration of the flexibility market into energy markets promises the introduction of new products and increases market liquidity. Management of the trading platform will be entrusted to an independent organisation Borzen, which was proposed by AGEN. Borzen, as an independent company and Slovenian market operator that manages and operates the market platform, can integrate the flexibility market with other energy markets, including the balancing market, which it oversees [23]. Furthermore, AGEN advocates the standardisation of flexibility products for use in energy markets such as the day-ahead market (DAM) and the intraday market (IDM), which is necessary so that flexibility products can be traded on the entire energy market. AGEN also recommends examining the integration of the flexibility trading platform with the platform for frequency system services, which is currently managed by the Slovenian TSO, ELES [23].

2.3 Flexibility services on the energy market

It is important to emphasise that our research relates to flexibility both in the area of production and in the area of energy consumption. Flexibility in the production and consumption of the energy can develop into a market service if there are customers in the energy market willing to pay for the flexibility service and service providers willing to provide this service for an appropriate fee. In this process, all parties in the chain between the customer of the service and the service provider must benefit from the implementation of the flexibility service in the market [23].

The list of considered services for the participation of EVs in the energy market within the Slovenian demonstrator is shown in Table 1. The initial list of services that were identified at the beginning of this task and that from their description connections to current setup of Slovenian demonstrator were possible. During multiple workshops, involving partners of the Slovenian demonstrator discussed the form of implementation and limitations of the setup. This led to the identification of services to be tested in the Slovenian demonstrator. Selected services that are going to be implemented and tested in the Slovenian demonstrator are marked in the following Table 1.

Table 1: List of considered services.

Services oriented towards	Considered flexibility services	Slovenian demonstrator
TSO	Primary Control (FCR, FFR)	No
	Secondary Control (aFRR)	No
	Tertiary Control (mFRR)	Yes
	Congestion Management	No
	Strategic reserve	No
DSO	Congestion Management	Yes
	Voltage Control	Yes
	Load Shifting	No
Aggregator	Flexibility for portfolio optimization	No
	Day-ahead Optimization	No
	Intraday Optimization	No
EV users	ToU Optimization	Yes
	Maximum power control	Yes

Table 1 presents the selected services to be for tested in the Slovenian demonstrator: mFRR, congestion management, voltage control, time-of-use optimisation, and Maximum power control. These services are explained in more detail in Chapter 4.

The selected services in task T4.4 are also oriented towards the users of EVs and take their priorities into account. This aspect of service development is explained in more detail in the following chapter.

2.4 EV user perspective

The user perspective is of great importance for the EV4EU project. Therefore, task T3.1 was dedicated to understanding their needs, concerns and perceptions. Interviews, workshops and surveys were conducted as part of task T3.1. The results show that the introduction of EVs in Slovenia is primarily motivated by economic and environmental considerations. However, users are concerned about the adequacy of the charging infrastructure, the associated costs and availability. On the other hand, citizens also have concerns about the longevity of EV batteries [26].

In general, EVs are perceived favourably by users as they appreciate the benefits such as reduced noise pollution, lower CO_2 emissions and potential long-term economic savings [26]. The environmental benefits are included in the services as less energy from renewable energy sources is curtailed and surplus energy from renewable energy sources can be stored for when it is needed.

Figure 2 from the **D7.1 Detailed definition and implementation plan of Slovenian Demonstrator** [11] is upgraded with the more specific representation of the market platform and the position of the user in the Slovenian demonstrator and is shown in Figure 1. All actors and technologies required for the participation of EVs in the energy market and for considering the perspective of EV users in the Slovenian demonstrator are presented in Figure 1.

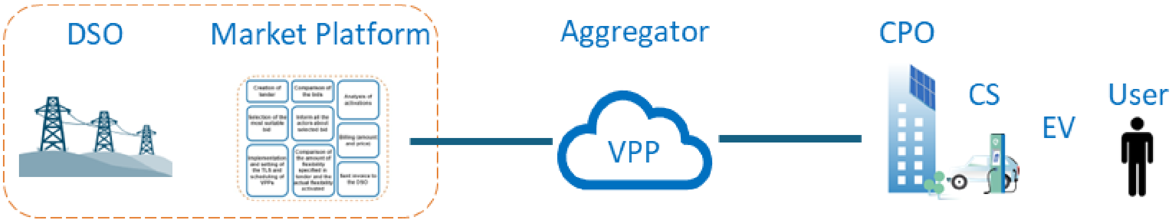

Figure 1: Layout of the Slovenian demonstrator

To address the economic aspect, the new services must offer financial incentives to EV users. To have the engagement of the users in these services, these incentives must be high enough to offset the costs associated with battery degradation. Battery degradation concerns will be addressed in a following deliverable of EV4EU project.

The project will explore different levels of customer involvement in the services. In Slovenia, for example, the management of V2X is undertaken by CPO or Virtual Power Plants (VPP), which can combine EVs' flexibility with other types of flexibilities, without constant (or minimum) user interaction. On the other hand, in the Portuguese demonstrator, users will interact with the V2X manager via an APP [26].

2.5 Assessment of EVs impact on Slovenian energy market

The participation of EVs in the Slovenian energy market is increasing. The reason for this is the growing number of EVs and charging stations (CSs), as estimated in **D1.1 Electric Road Mobility Evolution Scenarios** [1]. Based on the data for the future number of EVs from D1.1, we assessed the potential of V2G regarding the participation of EVs in the Slovenian balancing market.

2.5.1 Estimation of EVs to participate on the Slovenian energy market

In a first step, we estimated the minimum number of aggregated EVs that can fulfil the requirements for participation in the balancing market. These numbers were compared to the total Slovenian car fleet in 2021 to visualise the share of aggregated EVs. Then, based on the available data on the services demanded and offered on the Slovenian balancing market, we estimated the participation of EVs in these services for the period from 2025 to 2050.

The estimated minimum number of EVs for participation in the Slovenian balancing energy market is presented in Table 2. The results are presented for the State of Charge (SoC) interval most commonly used, ranging from 20% to 80%. In the evaluation, the occupancy of the CSs was taken into account, with a minimum CS occupancy of 12% and a maximum CS occupancy of 43% [27]. We also considered different ratios of EVs to CS, namely a realistic ratio (19:1) as reported for 2021 [1], an ideal ratio (10:1) [28] and the lag ratio (30:1). The lag ratio presents a scenario, that installations of CSs will not follow the growth of EVs. In our calculations, the average battery capacity of EVs was assumed to be 69 kWh [29].

Table 2: Estimation of required number of EVs to participate in the Slovenian energy market.

SoC limits for service participation		*20% to 80%*		
	Scenarios of EV to CS ratio	*ideal*	*realistic*	*lag*
minimum occupancy	*Required number of EVs*	*>2000*	*>3800*	*>6000*
	Percentage of EVs in Slovenia [%]	*>0.2*	*>0.4*	*>0.5*
maximum occupancy	*Required number of EVs*	*>600*	*>1100*	*>1700*
	Percentage of EVs in Slovenia [%]	*>0.1*	*>0.1*	*>0.2*

If we assume that EVs must cover the charging and discharging requirements of the grid at all times, we would need twice as many EVs. In this scenario, the minimum number of aggregated EVs, considering lag ratio, corresponds to 1% of the total Slovenian car fleet. This minimum was already exceeded in 2016 [1].

In the next step of our assessment, we compared the capacity of the EV batteries with the requests on the balancing market. The information on the quantity of energy that needs to be taken from or feed back into the grid was obtained from real data on the services requested by the Slovenian TSO, ELES, on the balancing market in 2021 [30]. The result is the share of services that an aggregator integrating a certain number of EVs could provide in all services on the balancing market. To illustrate the significance of results with future perspective, Figure 2 shows predicted number of EVs between 2025 and 2050.

The pessimistic and optimistic scenarios for the future number of EVs were taken from D1.1 [1]. The optimistic (green) and pessimistic (blue) scenarios, which are shown with thick lines, show the future share of EVs in the car fleet for a specific year in Figure 2 (y-axis on the left).

In addition, different ratios of EVs to CS were considered for these scenarios. Figure 2 shows an ideal (10:1) (dark lines) and a lag (30:1) (light lines) ratio of EVs to CS, for pessimistic and optimistic scenarios. The values for the estimated percentage of services that can potentially be provided by EVs start at 88% (y-axis on the right).

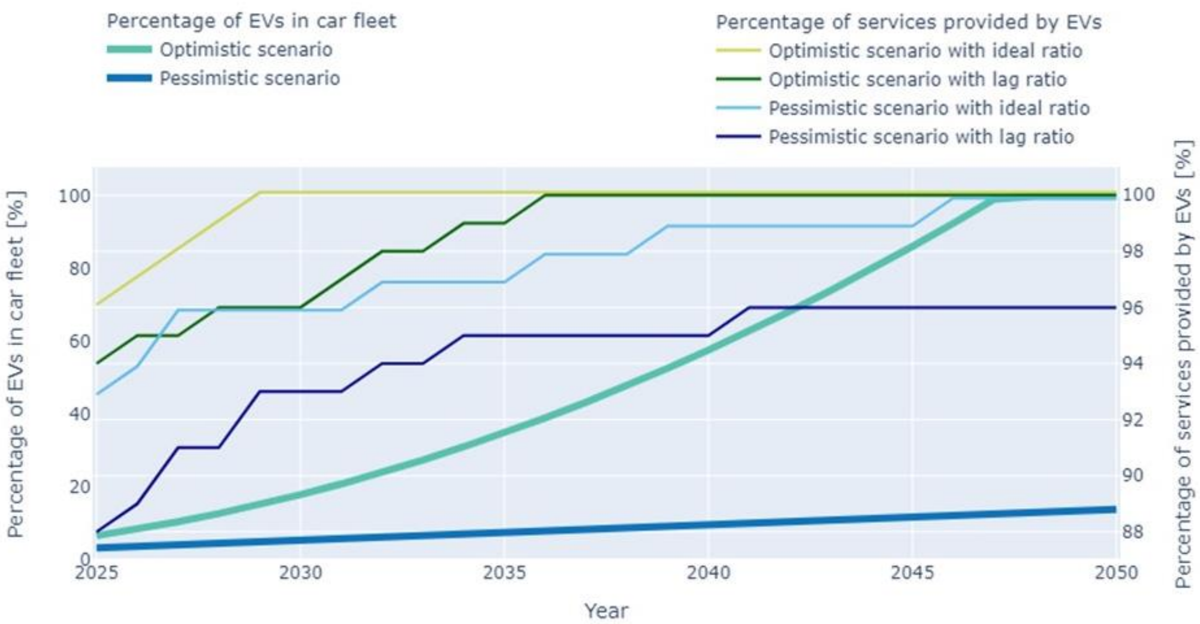

Figure 2: Graph of the estimated percentage of services provided by EVs for different scenarios of the percentage share of EVs in the car fleet and the ratios of EVs to CS (y-axis on the right). Graph also shows the change in the percentage share of EVs over the years from 2025 to 2050 presented in [1] (y-axis on the left).

From Figure 2, we can see that the provided service scenarios follow the growing number of EVs in the car fleet. As expected, the worst-case scenario, the pessimistic share of EVs with a lag ratio, shows the slowest growth. On the contrary, the steepest or fastest growing scenario is the optimistic share of EVs with an ideal ratio of EVs to CS.

A more detailed description of the estimation methods can be found in the next subsection. If we finalise the estimation at this point, the result from Table 2 shows us that there are already enough EVs in Slovenia in 2023 that, when aggregated, can fulfil the minimum requirements for participation in the balancing market. Another important finding from Figure 2 is the importance of the charging infrastructure. For example, the percentage of services provided by EVs in 2026 is higher in the pessimistic scenario with an ideal ratio than in the optimistic scenario with a lag ratio of EVs to CS. For EVs to play an important role in the flexibility markets, the growth of the charging infrastructure must follow the growth of EVs.

2.5.2 Participation of EVs in Markets

Our source for the balancing market data is the dataset presented in [30] that contains requests for the primary service, the Frequency Containment Reserve (FCR), the secondary service, the Automatic Frequency Restoration Reserve (aFRR) and the tertiary service, the mFRR. Both positive and negative balancing energy is displayed in 15-minute intervals.

The data on EVs were modelled based on datasets such as the number of trips in an hour of the day, the number of all car trips in a day, etc. [31]. We modelled the number of EVs on the roads, their consumption for trips, calculated the number of parked and connected EVs and estimated the flexibility they can provide in a given hour of the day. The data prepared in this way served as input for the comparative analysis. For different shares of EVs in the car fleet and different ratios of EVs to CS, we counted the number of services that could be provided. The share of EVs was increased in 1% increments from 1% to 100%. EVs and CS ratios were simulated between 10:1 to 30:1.

For each time interval, we compared the power demand from or fed back into the grid with the total capacity of all aggregated EVs at that time for a given share of EVs and ratio. More precisely, the difference between the current SoC and the predefined limits of SoC, at 80% for energy consumption (EV charging) and 20% for energy fed into the grid (discharging). If this difference was greater than the required quantity, we counted this as successful participation and changed the total capacity of the EVs accordingly.

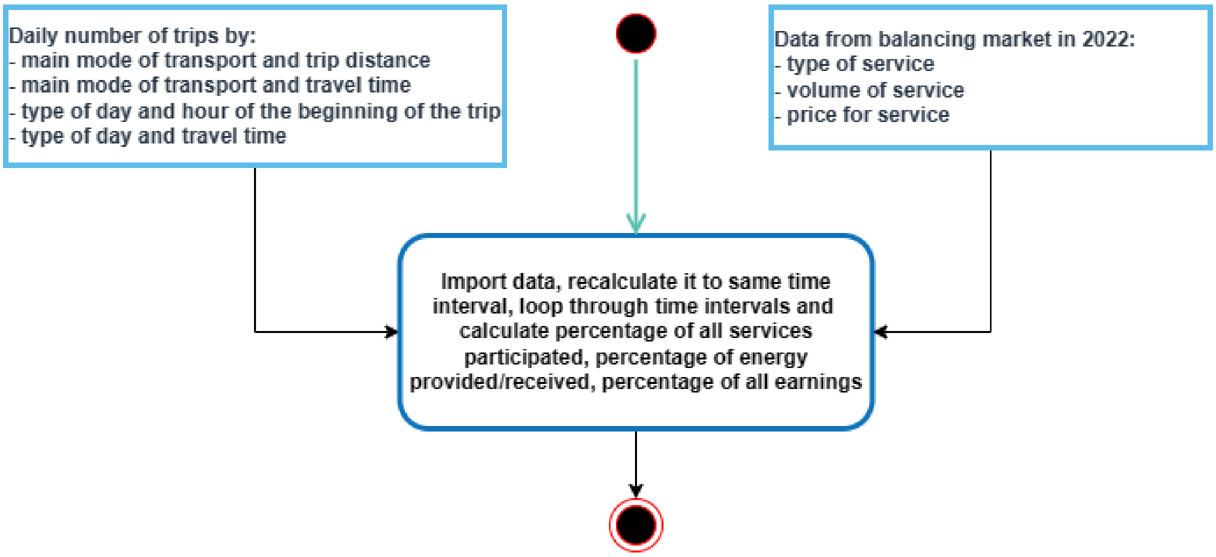

Figure 3: Steps for the impact of EVs on the Slovenian balancing market assessment. Inputs: mobility data (top left) and balancing market data (top right).

Figure 3 illustrates the implemented algorithm and shows the input data and the resulting variables. These results formed the basis for Figure 1, which shows the estimated percentages of services provided in the coming years assuming different scenarios for the development of the number of EVs. To obtain Figure 1, the results for different shares of EVs and different values for the ratio of EVs to CS were compared with the share of the predicted number of EVs for future years, as predicted in D1.1 [1], and marked accordingly.

The assessment of the impact of EVs carried out in chapter 2.5 can serve as input for **D3.4 Definition and Development of a City-Level Co-simulation Platform for V2X**, which assesses the impact of EVs at city level. Our assessment will also serve as input for the calculation of the KPIs of the Slovenian demonstrator in **D7.4 Analysis of Results**. In the follow-up of the project, the assessment from this chapter will serve as a starting point for the development of more complex tools that will evaluate the impact of EVs on the Slovenian energy market in more detail.

3 Market platform

In the Slovenian demonstrator, the market platform developed within OneNet project will be extended to meet demonstrator's needs. The OneNet market platform is aimed to become the standard platform in the EU [4]. Besides, the OneNet market platform, Open V2X Management platform is in development as part of Greek demonstrator, allowing the management of CS managed by CPOs. This deliverable focuses on the OneNet market platform. Chapter 5 collects additional information on demonstrators and local energy market rules in Greece, Denmark, and Portugal.

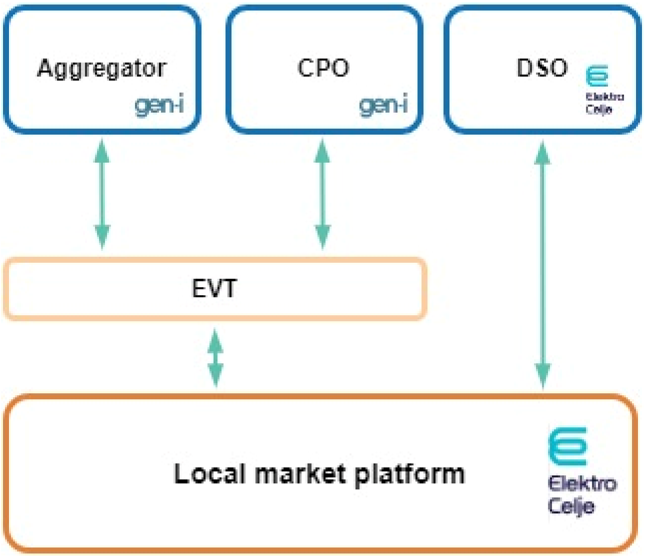

Figure 4: Integration of the local market platform into the energy market for the Slovenian demonstrator.

The developed market platform will act as a central communication hub, enabling information exchange between all actors shown in Figure 4 (DSO, aggregator, CPO). Actors other than DSOs have access to it via the second important point the Unified Entry Point (EVT, slo. Enotna Vstopna Točka). This is a unified system that serves as a data hub and provides seamless access to the billing and metering data as defined in [32]. In the Slovenian demonstrator, the market platform will be hosted by Elektro Celje, one of the five DSOs in Slovenia.

The general overview of the market platform is described in **D7.1 Detailed definition and implementation plan of Slovenian Demonstrator** [11]. The market platform will ensure interoperability between the actors. The IoT architecture will be used for the exchange of information between the actors, EVT and the market platform.

The market platform serves as a unified/standardised system through which actors offer or procure flexibility. In the Slovenian demonstrator, the market platform will enable the DSO, Elektro Celje, to procure the flexibility needed for different time periods. The market platform serves as a system through which the DSO can activate and procure flexibility. It also enables aggregators or CPOs, which in Slovenian demonstrator are both GEN-I, to bid on open tenders via EVT and offer their flexibility.

The implementation of the market platform in the Slovenian demonstrator is expected to improve the reliability of the grid, the integration of flexibility resources, the efficiency and the resilience of the grid infrastructure. The benefits the market platform will bring are also described in **D4.2 Scheduling and Real-Time Operation Strategies to Control V2X Flexibilities** [10] and **D4.3 Integration of V2X in Charging Point Operators and Virtual Power Plants Aggregation** [3].

3.1 Functionalities, protocols, and data formats of the platform

In Chapter 3.1, we describe the main functionalities of the market platform that is in development for the Slovenian demonstrator, as well as protocols and data formats for information exchange.

If the DSO (Elektro Celje), needs to procure flexibility for a certain period, it sends the message to the market platform with the aim of opening a tender on which all actors connected to the market platform can bid. In this case, the market platform must create a tender and notify all actors of its opening, which is one of the functionalities shown in Figure 5. Based on the available flexibility, the aggregator submits the bid for the open tender. After all bids for a particular tender have been received, the market platform must select the most suitable one and notify all actors of the selection. After the selection, the market platform implements and sets the Traffic Light System (TLS) [33] and plans the schedule of VPP. When the time for activation occurs the DSO sends an activation signal to the market platform, which forwards the signal to the selected aggregator via the EVT. The procedure is the same for the activation stop signal. After the activation is completed, the market platform analyses it and generates an invoice based on the amount of flexibility specified in the tender and the actual amount of flexibility activated by the aggregator. The invoice is then sent to the actor who procured the flexibility. The market platform in the Slovenian demonstrator will be used for the procurement and activation of more services which are outlined in the Chapter 4. The deliverable **D7.1 Detailed definition and implementation plan of Slovenian Demonstrator** [11] also presents the communication architecture and the actors in the Slovenian demonstrator.

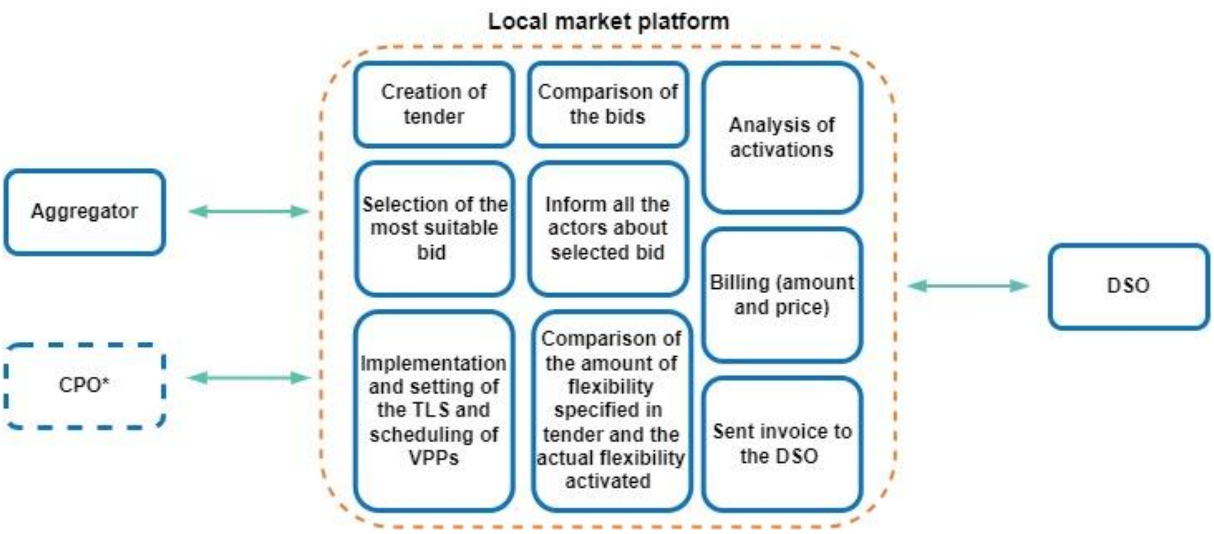

Figure 5: Local market platform main functionalities developed for the Slovenian demonstrator. *Future actors not participating in the Slovenian demonstrator.

The market platform uses Kafka Broker for communication and message exchange between the participating actors [34]. The Information Technology (IT) infrastructure of the DSO (Elektro Celje) sends and receives all messages related to the DSO with the market platform. The VPP, owned by the aggregator (GEN-I), communicates with other actors via the Message Queue (MQ) broker [35], which is VPP's single point of communication [4].

The market platform communicates with EVT via the MQ protocol, EVT then communicates with VPP or the aggregator via the Representational State Transfer (REST) protocol. The format of the messages used for the exchange of information between the market platform, EVT and VPP or aggregator is .xml. The market platform communicates with the DSO via the REST protocol. The data format for this information exchange is .json. The formats and protocols used in the information exchange between the actors in the Slovenian demonstrator are also given in Figure 7 Control and communication architecture in Slovenian demonstrator in **D7.1 Detailed definition and implementation plan of Slovenian Demonstrator** [11]**.**

4 Services for electric vehicles participation in markets

Chapter 4 provides an overview of the services that will be tested and demonstrated in the Slovenian demonstrator in Krško as part of the BUC 1 'Participation of Vehicle to Everything in the electricity markets through a virtual power plant' and BUC 6 'Participation of Vehicle to Everything in local Flexibility Markets' described in **D7.1 Detailed definition and implementation plan of Slovenian Demonstrator**. Selected services and main actors are presented in Figure 6. The activation and procurement of selected services in the Slovenian demonstrator is described in the following chapters in addition to the descriptions of the selected services.

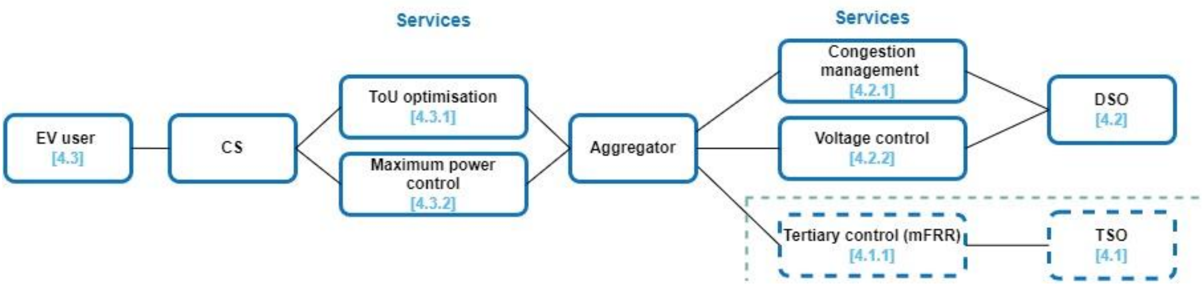

Figure 6: Services that will be demonstrated in the Slovenian demonstrator. Dotted line presents the service procured in the balancing market, that is going to be simulated in the Slovenian demonstrator. While other services are in relation to local flexibility market.

4.1 Services oriented towards TSO

In Slovenian demonstrator the activation and procurement of service oriented towards TSO, which TSO procures, will be simulated in order to test and demonstrate the participation in the balancing market, which is mentioned in Chapter 2.1. Figure 7 shows the service oriented towards TSO and the solution this service brings. The mFRR service is mainly used by TSOs to maintain the stability and reliability of the grid. The description of the selected service and its activation and procurement in the Slovenian demonstrator is described in the Chapter 4.1.1.

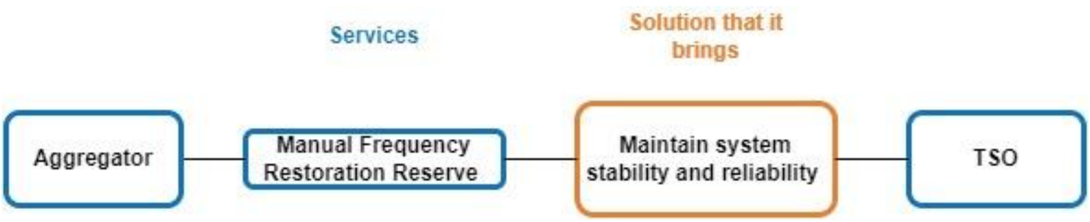

Figure 7: Mapping of services oriented towards TSO.

4.1.1 Manual Frequency Restoration Reserve (mFRR)

Manual Frequency Restoration Reserve (mFRR) according to ENTSO-E, is activated manually at the request of the grid operator and is used to relieve the automatic Frequency Restoration Reserve (aFFR) after the loss of large generation or load power, or to correct important forecast errors [36]. Although the objectives of mFRR and aFRR are the same, the requirements for the two services differ. mFRR usually has a longer duration and larger ramp rate, with fewer updates of measurements and forecasts required [37].

One of the actors participating in mFRR is GEN-I, aggregator in the Slovenian demonstrator. As already stated in the introduction of Chapter 4, the participation of GEN-I in mFRR will be simulated in our demonstrator. The reason for this is that Slovenian demonstrator (10 EVs) alone does not provide enough flexibility to participate in the mFRR market, as the limit is at least 1 MW [19]. The simulation will be based on real data, which will be adjusted to the quantities that are in the scope of the Slovenian demonstrator. When the TSO (grid operator), needs to activate an mFRR, it sends a signal to the national market platform, which will be simulated in the Slovenian demonstrator. On this platform, all actors participating in the mFRR, including GEN-I send their bid to participate in it. In case GEN-I is selected it participates in mFRR by adjusting the consumption (charging of EVs) and production (feeding energy from the EV batteries to the grid) of 10 CSs. By participating in mFRR, GEN-I contributes to the stabilisation of the grid and receives remuneration from TSO for its participation.

4.2 Services oriented towards DSO

Selected services, which are described in Chapter 4.2, help the DSO keeping local grid stable and reliable. The services also enable the DSO to reduce grid losses and delay or avoid grid reinforcement. The selected services and the solutions these services bring, are shown in Figure 8. The description of selected services and their activation and procurement are described in the next chapters.

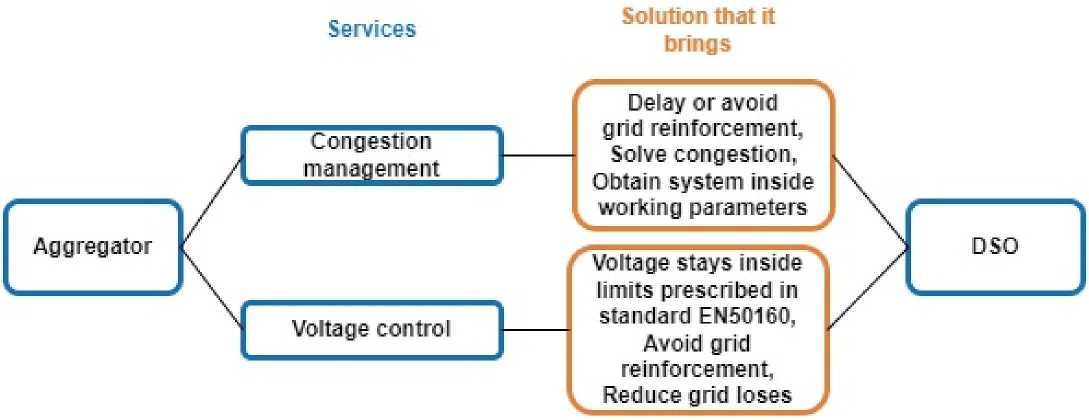

Figure 8: Mapping of services oriented towards DSO.

4.2.1 Congestion management

Necessity for a congestion management service arises when the power flows generated from the various energy sources violate the thermal limits of at least one grid element (e.g. by exceeding the power capacity of an asset). Congestion management means avoiding the overload of system components by reducing peak loads. There are control-based mechanisms for congestion management (e.g. direct access of TSO or DSO to prosumers loads for load curtailment), but also market-based approaches in which aggregators can participate [37].

Congestion management is a flexibility service that is primarily used in regions with a high proportion of fluctuating renewable energy sources. In congestion management, a TSO or DSO requests certain generators (or consumers) or aggregators to start or increase production (or reduce load), while other certain generators (or consumers, aggregators) are requested to stop or reduce production (or increase load) [37]. Congestion management can affect both the distribution and transmission grids.

In the Slovenian demonstrator Elektro Celje will recognise the congestion on certain substation in its local grid. The congestion will be monitored on substation “TP Inkubator Vrbna: 946” (1000 kVA), which is located at GEN-I office building in Krško. If the load in the substation exceeds 5% of its rated power, service congestion management is activated. When a congestion is detected or predicted, Elektro Celje sends a tender to the market platform (described in Chapter 3) with the aim of finding an aggregator that can solve the congestion in a specific substation. In Slovenian demonstrator, the aggregator is GEN-I, which sends a bid to the market platform to solve the congestion indicated in the tender. In case GEN-I's offer is selected, GEN-I and Elektro Celje receive a confirmation from the market platform and a contract is signed. When activation is necessary to address the mentioned congestion, Elektro Celje sends an activation signal to GEN-I. During activation, GEN-I adjusts the consumption (charging of EVs) and production (feeding energy from the EV batteries into the grid) of CSs to resolve the congestion. When the congestion is resolved, GEN-I receives the "Stop" activation signal from Elektro Celje, and the market platform handles the billing.

4.2.2 Voltage control

One of the most important parameters for determining the quality of the electricity supplied by grid operators is the voltage magnitude. There are two types of problems related to voltage control, the under voltage means that the voltage is below the lower acceptable limit, and overvoltage, when the voltage exceeds the upper acceptable limit. Voltage control services arise when the system operator is confronted with situations in which voltage in the grid is not within these acceptable limits [38]. The flexibility service of voltage control in the grid is mainly realised by finding a balance between the demand for reactive power and the generation of reactive power with the aim of keeping the voltage within the acceptable limits [37].

At the Slovenian demonstrator, Elektro Celje, needs to keep the voltage within certain limits. In our demonstrator, the voltage is monitored in the substation located at GEN-I office building in Krško. Elektro Celje has stipulated that it must activate voltage control if the voltage in the monitored substations is higher than 243 V (which is stricter than the EN50160 [39] power quality standards used in distribution grids). A lower acceptable limit for the activation of voltage control has not been set for the Slovenian demonstrator, as the voltage in the substation ‘TP incubator Vrbna: 946’ rarely falls below 235 V according to real data. When the voltage is outside the limits or is predicted to be outside the limits, Elektro Celje sends a tender for voltage control (for a specific substation) to the market platform. The GEN-I submits a bid for this tender. In case GEN-I is selected, Elektro Celje and GEN-I are notified and a contract is signed. When the time for activation, occurs Elektro Celje sends an activation signal to GEN-I, which adjusts its load to comply with the voltage limits. During the activation, GEN-I adjusts the consumption and production of CSs. When the voltage is back within the limits, the activation is stopped. The market platform manages the billing for the activated voltage control.

4.3 Services orientated towards EV users

Figure 9 shows the selected services oriented towards EV users that will be tested and the solutions that these services bring. The services from the Figure 9, aggregator in our case GEN-I will implement and utilise. The objectives of the selected services, oriented towards EV users are to reduce the cost of electricity consumption and increase profits. The solutions offered by selected services are linked to the aggregator and the EV user. This means that both actors can benefit from the correct use of these services and have a positive impact on the environment. The description of the selected services and their activation and procurement is presented in the next chapters.

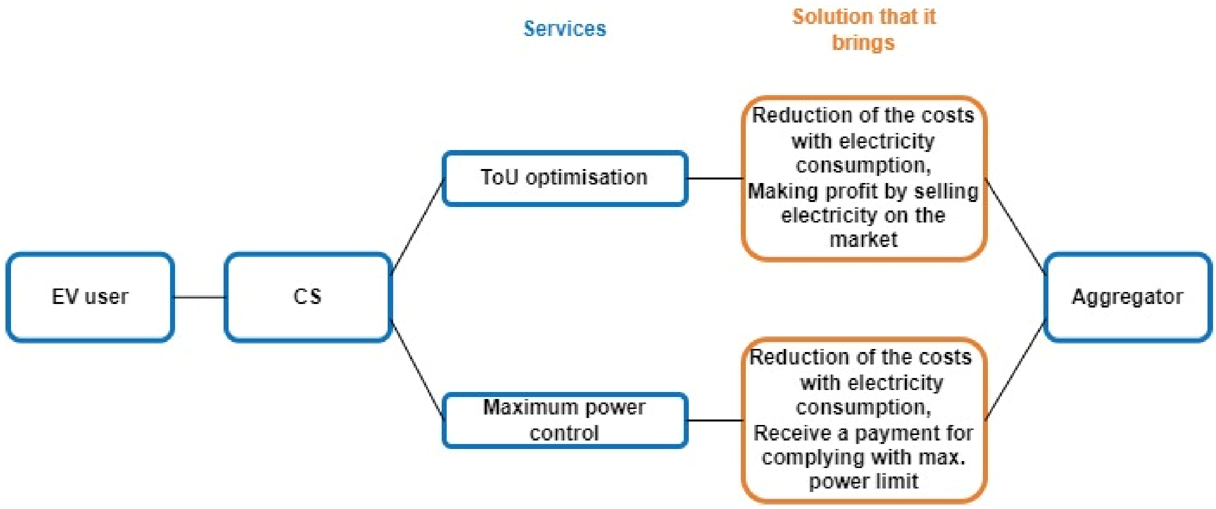

Figure 9: Mapping of services oriented towards EV users.

4.3.1 ToU optimisation

Time-of-use (ToU) optimisation is load shifting from high-price intervals to low-price intervals. This means that with ToU optimisation we can shift load and electricity production from more expensive (or cheaper - in case of production) intervals to cheaper (more expensive - in case of production) intervals. ToU optimisation can also be used to optimise participation in the services requested by the DSO. The aim of ToU optimisation is to optimise the times of use of certain actors in order to reduce the cost of electricity consumption or increase profit [37].

In the Slovenian demonstrator GEN-I wants to bring benefits to CPO and EV users. In our case, GEN-I uses the ToU optimisation service to achieve these goals. GEN-I optimises all ten bidirectional CSs so that the EVs are charged when the electricity price is low or is generated by the PV in its portfolio. This reduces the charging costs for the EV users. If the EVs provide enough flexibility, GEN-I utilises V2G technology and feeds the electricity from the EV batteries into the grid when prices are high or services are requested. The EV users are remunerated for participating in the flexibility services, which reduces the cost of EV charging and the operating costs of CPOs.

4.3.2 Maximum power control

With Maximum power control, the DSO or the aggregator can control the maximum power that a specific actor in its portfolio can consume or feed to the grid at given intervals. Maximum power control allows the DSO or aggregator to shift loads and reduce peaks. The maximum power that can be consumed or feed into the grid varies over time and depends on the conditions in the grid [37].

In the Slovenian demonstrator, Elektro Celje monitors the substation to which the CSs operated by GEN-I and its facilities are connected. In our case, if the load in a substation exceeds 20% of the substation's rated power or such a load is predicted, the Elektro Celje sends a signal to GEN-I to reduce its electricity production or consumption to a maximum of 20% of the substation's (‘TP Inkubator Vrbna: 946’) rated power. The GEN-I fulfils the limit set by Elektro Celje by providing a service called Maximum power control. With this service, GEN-I can determine how much power certain actors in its portfolio are allowed to generate or consume. In the Slovenian demonstrator, GEN-I uses the Maximum power control service for CSs, where it determines for each CS the maximum power that will be feed or consumed from the grid in a given time frame to fulfil Elektro Celje's requirements. By successfully performing the Maximum power control service, GEN-I helps to reduce the load in a given substation controlled by Elektro Celje. The aggregator and the EV users receive compensation for participating in this service.

5 Overview of other EV4EU demonstrators: flexibility services and energy market status

The focus of this deliverable is the Slovenian demonstrator, which is intended to test the integration of EVs into the energy markets. Therefore, the development of the flexibility market and the selected services refer to the situation in the Slovenian energy market.

The following chapters describe the market status, the timelines, the format in which the flexibility markets will be introduced and the specific aspects of the demonstrators in relation to the flexibility services for Greece, Portugal and Denmark.

5.1 Greek demonstrator: flexibility services and energy market status

At present, in Greece lacks any form of distribution level market. Based on current information, there is no plan, strategy or timetable for the development of the flexibility market in Greece.

The similarities and connections of the Greek demonstrator's business use cases (BUCs) with the services discussed in Chapter 4 are as follows. BUC 4, presented in **D8.1 UC specifications and demonstrator deployment plan** corresponds to ToU optimisation and focuses on the environmental impact in terms of services oriented towards EV users, mentioned in Chapter 4.3. BUC 4 of the Greek demonstrator is also related to the service voltage control mentioned in Chapter 4.2, but in implicit way. In addition, BUC 5, described in **D8.1 UC specifications and demonstrator deployment plan**, is linked with the Maximum power control service, which is oriented towards EV users, presented in Chapter 4.3. As far as services oriented towards DSO are concerned, BUC 5 of the Greek demonstrator refers to the congestion management mentioned in Chapter 4.2 of this deliverable.

5.2 Portuguese demonstrator: flexibility services and energy market status

In Portugal, the use of flexibility services by DSOs is not yet a reality. Nevertheless, in 2022, the main Portuguese DSO launched the Integrated Flexibility in a Market Regime (FIRMe) project with the goal of understanding flexibility requirements and test the market by raising awareness among the energy market actors and encouraging them to participate in this new local flexibility market.

The flexibility offers made in this platform will be used to avoid or delay new investments in the expansion of the grid. The results of this project will be used as a base for the definition of flexibility market that can be a reality in Portugal in a near future. This initiative is also aligned with the EU directive 2019/944 which mention that flexibility services should be adopted by each member state mainly by the DSOs.

In the EV4EU project, the Portuguese demonstrator is situated on São Miguel island in the Azores archipelago, distinct from the mainland (where the current status was described above). The Azores electrical system consists of nine isolated systems, one for each island, operating within a regulated market framework. In Azores, the EVs charging will be coordinated with wind generation avoiding wind curtailment. Wind curtailment is a major challenge in Sao Miguel island [40]. The second service that will be tested is the voltage control which will also be tested in the Slovenian demonstrator (Chapter 4.2.2). This service is not exclusive of islands but will mainly appear in rural areas with high penetration of photovoltaic systems and EVs. These two technologies will create voltage disturbances that can originate voltage deviation [41]. The participation of EVs in both services will be evaluated and future regulation and flexibility services can be defined based on Acuariid's experience.

5.3 Danish demonstrator: flexibility services and energy market status

As of the end of 2023, there only exist established markets for ancillary services on TSO level and none on DSO level in Denmark. Ancillary services such as fast frequency reserve (FFR) and frequency containment reserves (FCR) are handled in capacity markets, either national or as part of the European FCR cooperation (in DK1) and a common market with Sweden (in DK2), to set aside a certain capacity for activation in case of system imbalances. In December 2022, the Nordic TSOs launched a Nordic aFRR capacity market to align resources across the Nordic bidding zones. In June 2023 a Danish national market for mFRR went live that is so far focusing on coordinating between the Danish bidding zones. A Nordic mFRR energy activation market is expected to be established in Q1 2025, before being added to the common European mFRR energy activation market in the range of the MARI expansion in 2026. Figure 10 visualizes the current outlook for changes in the ancillary service market structure in Denmark, based on Energinet's projection for ancillary service markets in the range 2023 – 2040.

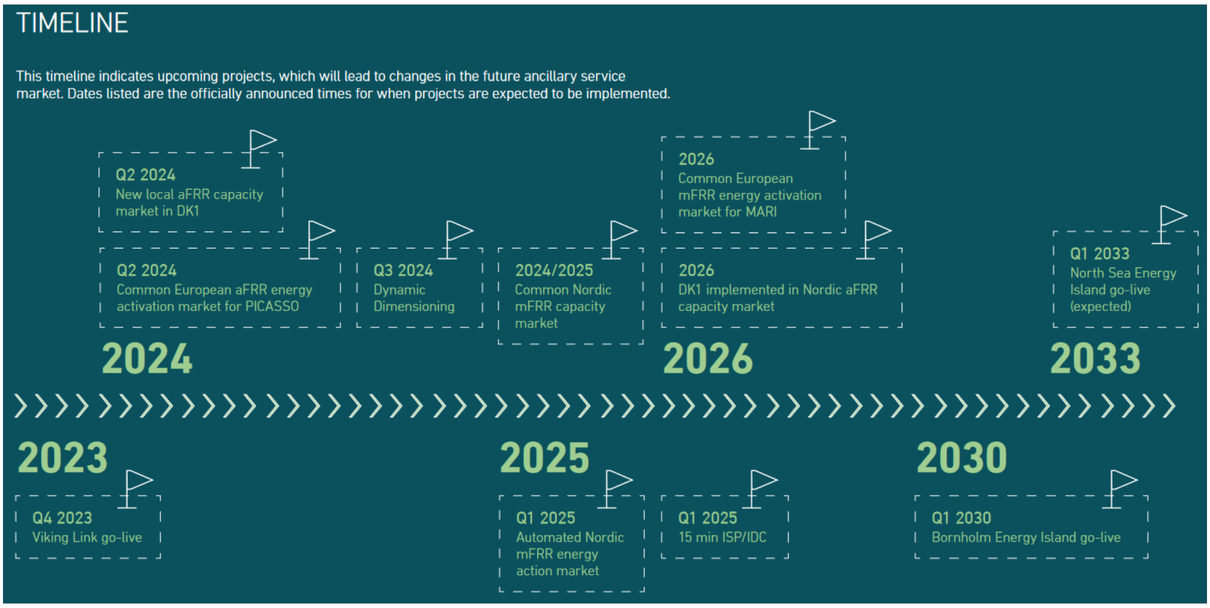

Figure 10: Danish timeline to indicate upcoming projects around future ancillary service markets. Dates listed are the officially announced times for when projects are expected to be implemented [42].

At DSO level, there does not exist an established flexibility market for distribution level services such as voltage control or congestion management [43]. Yet, several research initiatives developed pilot projects and investigated the benefits of a distribution level market for utilizing flexibility at household level. The project *EcoGrid 2.0*, for instance, involved 800 private households and summer houses on the Danish Island Bornholm, and set up a market framework to trade, activate and verify flexible consumption [44]. During the project, 209 trades and activations were performed with services directed at the transmission grid, and 36 with services to the distribution grid. One of the main findings of the project is that aggregators are needed to control the flexibility assets of individual households. For end-users, it is difficult to relate to trading flexibility, as their primary concern is their own consumption, expenses and comfort. Any type of flexibility market needs to take this into account and make access for end-users as easy as possible. The project *e2flex*, composed of a Danish consortium of an aggregator, a CPO, a DSO and DTU, aims at establishing flexibility products which DSOs can use to resolve congestion in tradable goods [45]. This will allow to build a market framework in the upcoming years, although there is not a clear time schedule yet.

In 2023, Denmark significantly increased the spread in variable grid tariffs at DSO level to steer consumption at household level which can be seen as an implicit way to untap flexibility at household level. The DSO tariffs are now structured in three steps with the lowest tariffs at night from 0 – 6, medium tariffs from 6 – 17 and 21 – 24, and peak tariffs from 17 – 21. This is done to disincentivize large consumption (of flexible units such as EVs) at typically already high loading periods.

The flexibility services to be tested in the range of the EV4EU project in the DK Demonstrator mainly revolve around behind-the-meter services such as renewable-based charging, price-optimized charging (ToU optimisation described in Chapter 4.3.1), and local phase balancing. Some efforts will be directed towards TSO level ancillary services such as frequency control (mFRR described in Chapter 4.1.1), as well as Maximum power control (described in Section 4.3.2) where the DSO could impose varying capacity limits for an EV parking lot requiring adjustments in how the local management system handles the EV charging requirements.

6 Conclusions

The deliverable *Impact of mass deployment of V2X in energy markets and services* outlines selected services for the participation of EVs in the energy market that will be implemented and tested in the Slovenian demonstrator. Therefore, the deliverable provides a more in-depth description of the services presented in **D7.1 Detailed definition and implementation plan of Slovenian Demonstrator** [11]**.**

In order to better understand the impact of EVs on the energy market, Chapter 2 analyses the market and the market platforms that serve as a central communication hub between the actors on the energy market. An overview of the current state of the Slovenian flexibility market is also provided. Selected flexibility services that enable the participation of EVs in the energy market are identified. In addition, EV users' perspective on V2X and their participation in such services is summarized, following outcomes of the **D3.1 EV Users' Needs and Concerns - Preliminary Report** [26]. Chapter 2 concludes with an assessment of the impact of EVs on the Slovenian energy market based on available statistical data.

Chapter 3 presents the market platform that is being developed as part of the Slovenian demonstrator within the EV4EU project. It presents the general idea of the market platform, its integration into the Slovenian demonstrator and benefits that the market platform brings. Besides main functionalities of the market platform, protocols and data formats used in communication between the market platform and other actors are also presented.

Chapter 4 gives an overview of the services that will be implemented and tested in the Slovenian demonstrator as part of the EV4EU project. Selected services are grouped into three groups, in relation to specific actors: TSO, DSO and EV users. The definitions of all five selected services as well as their activation and procurement processes are discussed.

The current status of the energy market, the timetables, the format in which the flexibility markets will be introduced and specific aspects and their relation to the services from Chapter 4 for other three EV4EU demonstrators are collected in Chapter 5.

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