ELVIS Project

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Report on the analysis of technical requirements and specifications

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Contents

ABSTACT

I. Introduction

I.1. Purpose and Organization of the Document

This document is the first deliverable (D2.1) of WP2 and describes the ELVIS high-level technical solution. It presents the overall architecture, functional description of the technical components and the scope for the first iteration of the ELVIS Solution. The deliverable document is structured as follows: The first chapter introduces purpose, organization, market overview, scope, audience and context of this document. The second chapter describes the different stakeholders and their interactions (operational and contractual) with the ELVIS technologies. In the third chapter, the high-level technical infrastructure of the component related with ELVIS Project are presented as they are developed in the time of writing of the current deliverable. The fourth section has a descriptive reference of the existing standards and protocols related with EV market. The fifth section provides technical details of the different ELVIS Solution components and how they are going to support the specified functionalities. Finally, the Business Cases and KPIs of the project are enlisted in section six and seven.

I.2. Electric Vehicles Market Overview

Within the past few years there has been a strong increase in sales of Electric Vehicles (EVs) globally, which will be magnified the following years based on the most recent EV market penetration scenarios (EV-Volumes.com, 2021). This growth trend has been disturbed by a setback year of 2020 due to Covid-19 pandemic effect but has recovered in just six months. In numbers, a total of 2,65 million new EVs have been sold during the first half (H1) of 2021, an increase of +168 % compared to H1 2020. This outstanding increase indicates a hyper-growth in the EV market; however, it needs to be seen relatively to the low base of H1 2020 due to Covid-19 pandemic. In more detail, in H1 2020, Global EV markets slumped -28 % compared to H2 2019 but they recovered within a year with a +28% year on year (y/y) increase in H1 2021. Western Europe sales, which were hit hardest during the pandemic (-40 % y/y in H1 2020), rebounded by +29 % in H1 2021. For the year 2021 6,4 million sales and 98 % growth y/y has been forecasted (

Figure 2), with the trend in volumes/shares, purchase cost reduction, solid policy support and higher public awareness indices of the last 12 months all underpin this forecast. Main driver for this exponential growth in sales is the incentives provided by many governments encouraging vehicle buyers to choose an EV. For example, seeking to become the first nation to end the sale of petrol and diesel cars by 2025, oil-producing Norway exempts fully electric vehicles from taxes imposed on those relying on fossil fuels (Time for Norway to tax luxury electric cars, IMF economists say, 2021). Similarly, buying an EV in Germany is supported by up to 4000€ (Regulatory environment and incentives for using electric vehicles and developing a charging infrastructure, 2022). Other common incentives in countries are free parking places or reduced taxes.

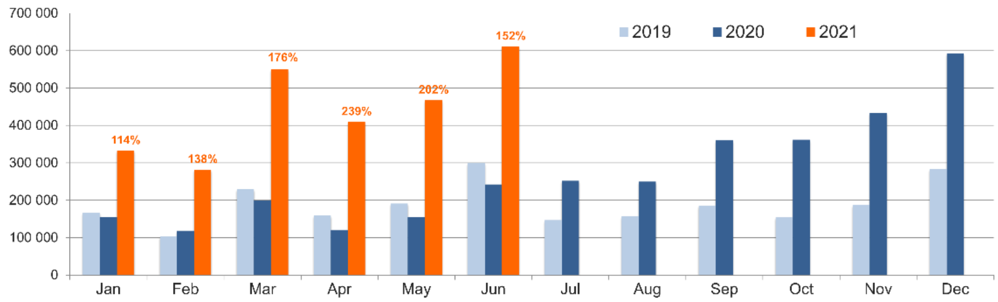


Figure 1 Global monthly plug-in vehicles sales & year over year growth

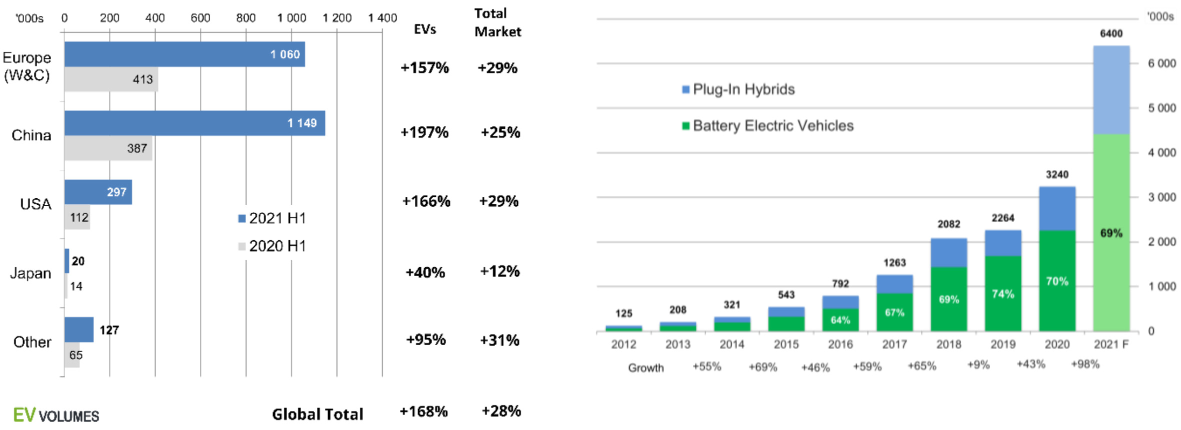


Figure 2 Global pug-in vehicles sales

On 17 June 2020, the Greek Ministry of Environment and Energy introduced new legislation and announced financial, tax and charging-point-installation incentives to encourage uptake of EVs (Energy, 2020) (Table 1). These incentives were aim both private car owners and companies interested in acquiring, replacing, or disposing their old cars. As shown in Figure 3, from 2014 to 2020, there has been an (albeit cumulatively low) upward trend in the number of EVs in Greece (European Alternative Fuels Observatory (EAFO, 2020), n.d.). In 2020, there were 561 battery-electric vehicles (BEV) in Greece.

Table 1 Electric vehicle incentives set by the Greek Government

	Subsidy for EV purchase	***Additional subsidy for disposing old vehicle***	***Subsidy for EV charger installation***
Private car owners	15% of the purchase price	€ 1000 subsidy	€ 500
Companies		Not applicable	30% against the value of the charger or 50% of the value of the charger when it is installed for public use by the company or 70% of its value for island-based companies

Light trucks and vans	15% of the purchase price or up to €5,500	€1,000	Not applicable
Taxis	25% of the purchase price or up to €8,000	€2,500	Not applicable

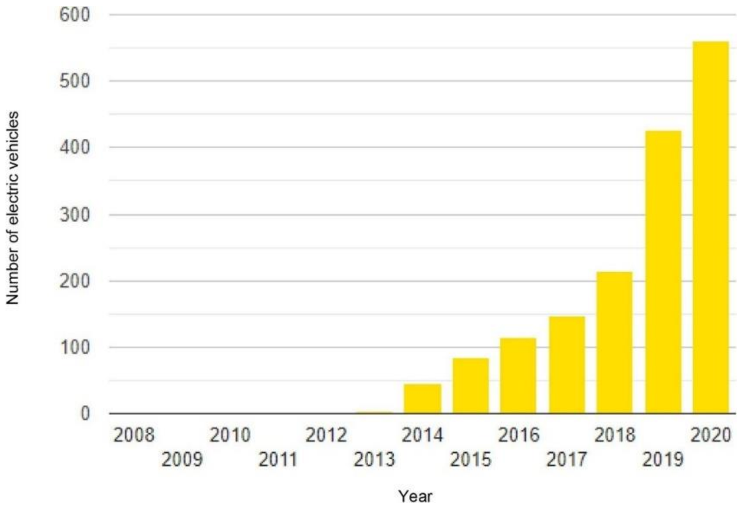


Figure 3 Total fleet of electric vehicles in Greece

There are currently more than 400,000 public charging points installed to support the more than three million EVs in use globally. This number is expected to rise significantly based on the global EV-adoption forecast by 2030, that estimates an annual EV sales rate greater than 31.1 million (Electric vehicles, Setting a course for 2030, 2020) and a cumulative number of EVs greater than 250 millions (Electric vehicle stock in the EV30@30 scenario, 2018-2030, IEA, Paris, 2020). Simply replacing gas stations with charging stations or adding more charging points that are the size of gas stations won't be sufficient to service the expected number of EVs in use.

In 2020, Greece had an average of three EVs per charging point, higher than the European average, which was equal to five EVs per charging point (European Alternative Fuels Observatory (EAFO, 2020), n.d.). This number though cannot be used as an absolute index of Greece's public EV charging infrastructure as the EVs penetration remains low. For example, in Norway, the country with the highest market penetration of EVs worldwide, 36,406 EVs have been registered in 2020 comprising 45.6% of the new car registrations (Global EV Outlook 2019, 2019) compared to Greece's only 211 newly registered EVs, which correspond to only 0.4% of its market share (European Alternative Fuels Observatory (EAFO, 2020), n.d.). In addition, there were only four "fast charging" points per 100 km of highway in Greece. This number is considerably lower than Europe's average, which is 39 and Norway's 833 "fast charging" points per 100 km of highway, respectively. It is worth highlighting that Norway also has a smaller highway network of 523 km compared to Greece's 2309 km (European Alternative Fuels Observatory (EAFO, 2020), n.d.).

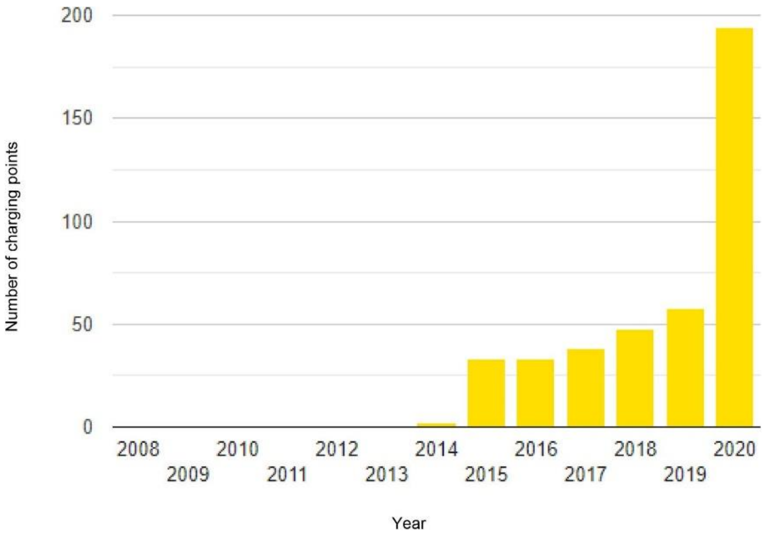


Figure 4 Total number of public charging points in Greece

I.3. Scope and Audience

This deliverable describes the high-level architecture of the ELVIS solution, the technical requirements, and the specifications. It will serve as technical basis and will provide guidelines to the technical WPs involved in the development of the ELVIS solution components. The design of the different components will be described in more detail in later deliverables. The second chapter of this document introduces the actors that are related to the ELVIS Platform and their relationship with it. The proposed architecture will be validated with simulated and real-life data.

II. Stakeholders

The first step for describing and understanding ithe ELVIS ecosystem is to identify the stakeholders, their interactions and business models. Many different stakeholders do exist, directly and indirectly impacting the ELVIS scope. Table 2 shows the major stakeholders identified that are directly relevant with the EVIS system, along with a basic description of their role and their main interests. The main terminology of Electrific project (Electrific, a European Union's Horizon 2020 Project, 2020) is used in this report.

Table 2 Overview of ELVIS Stakeholders

STAKEHOLDER	*Short Description*	*Interests*
EV Owner (EVO)	Human actor, using a private owned EV.	• Lower charging cost • Lower maintenance cost • Increased driver satisfaction • Longer battery life
EV Fleet User (EFU)	Human actor, using an EV belonging to a commercial EV fleet.	• Lower charging cost • Lower maintenance cost • Max. availability for driving • Faster charging sessions

EV User (EVU)	The EV User refers both to “EV Owner” and “EV Fleet User” in order to describe common characteristics and needs.	• Lower charging cost • Lower maintenance cost • Increased driver satisfaction • Longer battery life • Max. availability for driving • Faster charging sessions
EV Fleet Operator (EFO)	A fleet of EVs under common management	• Lower charging cost • Lower maintenance cost • Longer battery life • Ability to support more vehicles with less infrastructure • Maximum availability of the EVs of the fleet for driving
Distribution System Operator (DSO)	The entity responsible for the operation of the electricity distribution network.	• Secure, economic and reliable network operation
TSO	The entity responsible for the operation of transmission system.	• Secure, economic and reliable system operation
Energy Supplier (ES)	The entity that purchases energy from the wholesale electricity market and sells it to end-consumers, CSOs	• Maximum profits from energy trades • Minimum imbalances
Charging Station Owner (CStO)	The entity that owns CS (public, private, commercial)	• Easier stations’ management • Investment viability
Charging Station Provider (CSP)	The entity that manages/operates CSs	• Maximum profits from EV charging
Charging Point Operator (CPO)	*Alternative terminology for CSP*	
Electric Vehicle Aggregator (EVA)	The entity that provides services to CSPs, EVOs, EFUs, TSO and DSOs through the smart charging control.	• Profit from energy trading • Optimal market participation • Customer engagement
E-Mobility Service Provider (EMSP)	The entity that offers EV charging services to EV drivers, mainly by enabling access to a variety of charging points around a geographic area.	• Add-on features for e-mobility ecosystem • New sources of revenues • New marketing and promotion opportunities

The following section provides an overview of the involved stakeholders as they are defined at the time of the writing of this document. It provides a definition for each stakeholder with their role in the charging process and how ELVIS platform adds value to their main business interests.

II.1. Stakeholders Description

II.1.1. EV Owner (EVO)

EV Owners are the human actors that own and use a private EV. Generally, EVOs consider EVs as an alternative to vehicles with combustion engine for lower fuel costs, better mobility experience and less environmental pollution. EVOs vary in behavioral patterns and each type of EVO has different needs and priorities when it comes to using their EVs.

II.1.2. EV Fleet User (EFU)

EV fleet users (EFUs) drive EVs that belong to commercial EV fleets. They can be differentiated between internal and external EFUs.

Internal EFUs are drivers that work for the company owning the EV fleet. Examples are drivers of post offices or courier services which operate EV fleets or bus drivers using electric buses for public or private transportation. In addition, taxi drivers using an EV that belongs to a taxi company or employees that can use cars of their company belong to this category. In contrast to EVOs, internal EFUs often do not have a broad leeway in their actions. Bus drivers for example have a predefined route and schedule from which they are not allowed to diverge from. Taxi drivers on the contrary have no predefined schedule but instead they have ad-hoc calls for new trips. Therefore, a taxi driver wants a full battery as much possible in order to be ready for longer journeys. However, in cases where a certain freedom of action is provided to the internal fleet EV user, this can be leveraged using ELVIS in a similar way as with EVOs.

External EFUs drive EVs that belong to a fleet that is accessible to external users. In contrast to internal EFUs, external EFUs do not work for the company operating the fleet. Examples of external fleet users are EV sharing users or EV users renting or leasing EVs, for example in tourists' Greek islands like Rhodes (ASEM ISLAND MOBILITY SERVICES, 2021). Depending on the company and business model, both internal and external fleet users might be responsible for charging the EV themselves. In other cases, however, the EV Fleet Operator is responsible for EV charging.

II.1.3. EV User (EVU)

The term EV User (EVU) is used for common reference to EVOs and EFUs. They are also can be categorized in internal EVUs (EVOs and/or Internal EFUs) and external EVUs (External EFUs).

EVUs are key players for ELVIS since their willingness to participate in smart charging programs is a prerequisite for the deployment of smart charging business models. The decision for participation in a smart charging program it might be an individual one (e.g., EVO) or a company decision (e.g., EFUs of EV flees for transportation services, described in EV Fleet User (EFU)). Whatever the case, the charging patterns are highly related to the scope of EV usage and their accurate prediction is crucial for the efficient market participation of Suppliers and EV Aggregators. EVUs might also use EMSP services like charging session reservation, mobile charging payment via mobile applications to improve their charging experience.

Using historical data Helmus, Lees and Hoed (Helmus, Lees, & Hoed, 2020,) categorized the EVUs in several types based on their charging location and timing profiles. Identifying the EVU type is crucial when it comes to optimizing a bidding strategy or developing a smart charging algorithm. Using clustering methodologies on data consisting by 5.82 million charging transactions from January 2017 until March 2019 of 133 thousand EV users made on 7079 Level 2 public Charging Stations, they proposed nine distinct clusters of user types characterized by different charging session profiles (charging distributions). The conclusion drawn from the aforementioned research is that the most important variables that characterize EVUs in different types is the distinction between daytime and overnight sessions. The second largest distinction was based on distance, having either the same or different location as the former session. The start time and duration of the session appeared less distinctive and required three categories to set a split short, medium, and long duration. These results are based on specific EV charging sessions data. However, a similar kind of clustering and profiling is anticipated in all e-mobility ecosystems as all actor in the ecosystem share common actions and behavioral patterns.

Table 3 User Type Distribution and Supplementary Properties

User Type	**No. of charging sessions**	**Percentage (%)**	**# Car sharing**	**# Taxis**	**Weekly charging sessions**	**Mean estimated battery size (kWh)**	**Mean transaction volume (kWh)**
1	2391	8.9	0	5	1.42	15.12	8.17
2	3570	13.2	0	38	1.86	23.48	14.07
3	3818	14.1	0	57	2.17	23.67	12.37
4	2281	8.4	0	5	0.94	13.53	6.22
5	2236	8.3	0	17	1.70	12.81	8.25
6	5676	21.0	1	163	4.6	15.71	8.88
7	4003	14.8	0	194	3.68	24.58	13.16
8	1525	5.7	0	25	4.14	12.68	7.13
9	1514	5.6	398	27	4.78	19.55	9.19

User **type 1** is **a daytime user** with an average of 1.42 charging sessions per week particularly at weekdays. This user type has 40% of its sessions strictly during office hours and about 40% of its sessions outside office hours, yet still during daytime. The 20% of sessions is during the weekend of which only 0.1% is overnight charging.

User **type 2** can be considered as **an infrequent residential user** as he only has 1.8 sessions per week. On average 72% of its sessions are overnight charging and 28% is short duration charging.

User **type 3** is typically **an all-round user with a mixture of office and residential charging**. This user type has on average 23% of its sessions during office hours, 47% of nighttime charging and 30% of opportunity charging. Contrary to what may be expected by the wide portfolio of behavior, is that this user type has on average 2 sessions per week with an energy uptake of half the battery size. We therefore assume this user charges at (semi-) private or fast charging locations as well.

User **type 4** is **a public charging user** since he is frequently visiting locations nearby public charging infrastructure. This user type has close to one weekly charging session of less than 4 h duration. The sessions are uniformly distributed over the days of the week. The large average number of CSs used (Table 3) suggests multiple destinations (e.g., shopping, sports, health).

User **type 5** is most related to **the office charging stereotype**. This user type is a daytime user and has about 1.7 charging sessions per week of which more than 65% are during office hours and around 35% is typically opportunity charging. Only 4% of their sessions are overnight charging sessions.

User **type 6** is significant in the total population (21%) and considered most related to **the stereotype of a residential user**. This user type has a high frequency of charging of 4.60 times per week and has on average 75% of overnight charging sessions in its portfolio. The other 25% are short session during daytime of which 30% is in the weekend.

User **type 7** has the **same pattern of frequency as user type 2** therefore he can be categorized as **an infrequent residential user**. Yet, user type 7 has a large fraction of sessions that occur at a different location than the previous session, which is not the case for user type 2. This user type is typically present in areas with high EV uptake and charging infrastructure maturity. User type 7 also drives significantly larger distances between sessions than other user types.

User **type 8 is a daytime and office charging user** with 60% of its sessions during office hours and 23% of its sessions at the same day outside office hours. Contrary to the previous types, this user type is dominant on short session instead of medium. The locations of the most-frequently used CPs of these user types are typically in work areas.

User **type 9** can be considered as **a random user type** with noisy behavior as this user type has little to no sessions at the same location as the previous session. The start and end times of this user type are multimodally distributed over the day without significant tendency towards a specific hour. All the known **car sharing** EVs are clustered with this user type in this cluster (Table 3).

II.1.4. Distribution System Operator (DSO)

Distribution system operator (DSO) is the operating manager (and sometimes owners) of electricity distribution networks, operating at low (LV), medium (MV) and, in some cases, high (HV) voltage levels.

The DSO provides the grid infrastructure to which the CSs are connected, however, do not directly sell this service to the CSP. The reason for that is that the operation of power grids is very expensive and since it is not worthwhile to lay out the supply technology redundantly in one area, there are no competitors at the same place. Nevertheless, consumers have a great interest in the fact that the prices for the gird usage are calculated fairly. To ensure that network operators do not earn monopoly profits and operate the networks as cost-efficient as possible, power grid and gas grid operators are regulated by a national authority (In Greece: Hellenic Electricity Distribution Network Operator, HEDNO).

Due to high penetration of Distributed Energy Resources (DERs) in distribution systems the power system operation nowadays has to deal with more and more challenges, mainly on grid congestion (power flows that violate thermal limits of the elements) and voltage stability, making the DSO's core mission of providing a secure electricity supply and quality of service increasingly challenging. Thus, DSOs seek alternatives to high-cost distribution network upgrades that cannot follow the high rate of DER penetration and usually meet social non-acceptance. One way towards this objective is to develop their networks to face the new scenario and to allow increasing distributed generation and plug-in EVs penetration. Instead of only extending / reinforcing physical infrastructure, which is extremely costly to local communities, alternative solutions are being introduced based on IT, communications, sensors and automation, allowing DSOs to actively manage the varying generation and demand. The most promising alternative seems the deployment of DERs flexibility in a cost-efficient way in order to tackle congestion management problems. The recent European regulatory framework supports the procurement of flexibility services by DSOs for the efficient, reliable, and secure operation of the distribution system in accordance with transparent, non-discriminatory, and market-based procedures. To this context EVs are emerging among the DERs as a promising flexibility source.

II.1.5. Energy Supplier (ES)

Electricity Suppliers (ESs) purchase energy from the wholesale electricity market and sell it to end-consumers (industrial, commercial or residential loads). The try to offer and competitive rates and usually provide a variety of pricing and contractual options to the end-consumers. In the context of ELVIS, ESs supply the energy of the CSs and have contractual relationship mainly with CSPs and EVOs but in other cases with EFOs too.

The key interests of the ESs on ELVIS are:
1. The opportunity to sell more energy, as the smart-charging features could allow faster, more reliable, and better distributed charging sessions, leading to more available sessions, and therefore to more revenues, and
2. The contractual relationship with the EVA that will manage the smart charging in order to avoid additional charges due to imbalances.
3. The opportunities for participation in a smart contractual framework that provides faster and more convenient, billing, settlement and transactions environment.

II.1.6. Charging Station Owner (CStO)

Charging Station Owners (CStOs) can be categorized in internal or external CStOs. The aim of Internal CStOs is the development of a charging infrastructure for their internal fleet. For example, a Courier service company installs CSs for the charging needs of its own EV fleet. In the opposite, External CStOs install CSs for use by external EVUs either for profit or for other reason like social awareness of EVs and promotion of EVs adoption (e.g., municipalities initiatives). External CStOs can manage CSs on their own or can delegate management to independent CSPs to maximize profit/revenue. However, the latter is not always the case. Today, for example, communities own many charging stations which are open to the public. They usually do not operate them themselves, but instead have a contract with a CSP. The profit/revenue the CSP gets by operating the charging station is nowadays often not forwarded to the communes. Therefore, communes in the role of a CStO do not have the goal to maximize profit, but instead have other reasons, like promoting the use of EVs or making the area more attractive. However, such in other cases, the profit/revenue the CSP experiences are (partially) forwarded to the CStO.

EVOs that own a charging station usually have the goal to 1. conveniently charge their car at home, but they also have the goal to 2. decrease charging costs, 3. maximize the use of renewable energy (especially if they have locally installed renewable energy source generators) and if they offer their CS to the public, to 4. make profit. Dependent on the goals and business model, ELVIS will offer a platform with services to reach the goals by all four Objectives.

II.1.7. Charging Station Provider (CSP)

The CSP (also known as CPO) is responsible for the operation, maintenance, and management of the charging infrastructure (and probably the installations). It is not necessary for a CSP to be the owner or the investor of the charging station, but he can operate multiple charging infrastructures simultaneously. The CSP also ensures the appropriate functioning of the charging network. This can include diagnostics, maintenance, price setting and data management. Like the EFU and EFO the CSP can also be an internal or external CSP. While the latter is offering charging services to the public, internal CSPs only offer charging services to company members.

II.1.8. Electric Vehicle Aggregator (EVA)

The EVA is a trader of flexibility, sitting centrally in the flexibility value chain (USEF, 2021), between the CSPs, EMSPs and EVO/EFUs on one hand and flexibility requesting parties like DSO and TSO on the other. The EVA is responsible for maximizing the value of flexibility in the charging process of numerous plug-in EVs, aggregating it into a dispatchable portfolio, creating services that draw on it and offering these to different markets, serving different market players. The value received by the EVA in return is shared with CSPs and EVO/EFUs as an incentive for them to participate in smart charging programs.

To provide his services, real-time communication between the EVA and the charging stations infrastructure is necessary via suitable communication protocols (e.g., OCPP (Open Charge Alliance, n.d.). Thus, close cooperation between EVA and CSPs, EMSPs is necessary.

The EVA can also be the same entity with the Energy Supplier or separate entities. In each case the EVA serves a different strategy to maximize the value of the dispatchable EV portfolio.

EVA is a key stakeholder for ELVIS since ELVIS tools serve mostly the EVA need for optimal market participation and efficient smart charging.

II.1.9. E-mobility Service Provider (EMSP)

The EMSP provide services, in most cases IT services, to enable access to the charging infrastructure and to ease monitoring of the charging infrastructure. These services are usually provided via a software platform that offers an interface as an intermediate between the related actors of the charging ecosystem with the charging infrastructure.

Furthermore, EMSPs develop solutions that helps EVUs to find charging stations, to reserve charging sessions, to start charging events, to check CS specifications, to find car sharing services, to use quick and practical e-billing solutions as well as charging roaming services, etc. It is very common that EMSPs to not directly provide their services to EVUs but to CSPs who offer a wider variety of services to the EVUs including the one developed by the EMSPs (Stryja, Fromm, Ried, Jochem, & Fichtner, 2015).

On the other hand, EMSPs also develop solutions for the CPSs regarding the EV fleet management. These solutions are necessary to CSPs to have a close monitor of their charging network, charging utilization information, fleet analysis and consulting.

Typically, EMSPs serve only registered customers, but may also enable access for unregistered users, as is sometimes mandated by local law. The EMSP's platform is usually the intermediate for the settlement processes of the charging sessions and the payment procedures as well. As a separate service EMSPs may also want to provide access to 3rd party charging stations through roaming. In these cases, the CSPs typically offer the service to its existing customer base.

II.1.10.Transmission System Operator (TSO)

The Transmission System Operator (TSO) is an entity entrusted with transmitting electrical energy on a national or regional level, using fixed infrastructure. The term is defined by the European Commission. The certification procedure for Transmission System Operators is listed in Article 10 of the Electricity and Gas Directives of 2009 (DIRECTIVE 2009/73/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 July 2009 concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC, 2009). Independent Power Transmission Operator S.A. (IPTO) is the nominated TSO in Greece. All the different aspects of rules and regulations regarding Independent Transmission Operators in EU are being described in chapter IV (Articles 17-23) of the same document. Due to the costs to establish a transmission infrastructure, including main power lines and associated connection points, a TSO is usually a monopoly, and as therefore often subjected to regulation. An overview picture of the role of the System Operator in a wholesale electricity market is to manage the security of the power system in real time and co-ordinate the supply of and demand for electricity, in a manner that avoids fluctuations in frequency or interruptions of supply. The System Operator service is normally specified in rules or codes established as part of the electricity market.

Safety and reliability are a critical issue for TSOs, with natural hazards and generation/consumption imbalances are a major cause of concern. To minimize the probability of grid instability and failure, regional or national transmission system operators are interconnected. All TSOs are obligated to operate a balancing market to handle imbalances between electricity supply and demand. Through the balancing market mechanisms, they ensure adequate reserves that will allow to overcome any sudden system contingencies. TSOs achieve this by determining the optimal combination of dispatchable resources for each market trading period, instructing them when and how much to deviate their initial production of consumption schedule (a.k.a. Market Schedule). Sophisticated energy modelling and communications systems are essential tools for TSO operations.

The ELVIS technologies can provide valuable services to the TSO by controlling the charging of numerous EVs and providing this controllability as a new balancing resource. Thus, EV batteries consist an additional resource for the TSO to maintain the balance in the power system, and on the other hand an opportunity for the e-mobility ecosystem for profits from its participation in the balancing market.

II.2. Stakeholders Interactions

After providing an overview of the stakeholders in the last section, in this section the basic interactions between them will be described. The interactions include data and cash flow streams as well as contractual relationships.

II.2.1. Contractual Framework

Table 4 Contractual Relationship among Stakeholders.

	EVO	EFU	EFO	DSO / TSO	ES	CStO	CSP	EVA	EMSP
EVO							(+)		(+)
EFU			+				(+)		(+)
EFO		+					+		
DSO / TSO					+			+	
ES				+			+	+	
CStO							+		+
CSP	+	+	+		+	+		+	+
EVA				+	+		+		(+)
EMSP	+	+				+	+	(+)	

* (+) means optional case

In Table 4 the Contractual Relationships among the Stakeholders are presented. A brief description for the charging related stakeholders can be listed as:

1) A contractual relationship between EVA and DSO is necessary for the provision of flexibility services from the EVA to the DSO. This relationship should define all the aspects (legal, operational, procedural, technical, financial, pre-qualification) between the DSO and the EVA.

2) A contractual connection between the EVA and the ES is possible so that the EVA is committed to inform the ES about flexibility availabilities, thus neutralizing ES's impact from smart charging.
3) A contractual connection between EVA and CSP is necessary. This contract should define the aspects for real-time access of the EVA to the CS data and charging power modulation upon EVU's smart charging consent.
4) A contractual connection between EVA and EMSP is possible. This contract could define the aspects for real-time dynamic pricing provided by the EVA to EVUs via the EMSP services.
5) A contractual connection between the ES and the CSP is necessary for the supply of energy.
6) A commercial connection/relation of the CSP and/or EMSP with each EV related stakeholder (EVU, EFU, EFO) is necessary for the charging services to be provided. A reservation of a charging session and the acceptance of CSP's Term of Use can play this role without any other additional contractual arrangement. When reserving the session, the EV User should select if he accepts his participation in a smart charging program and he should also declare the desired departure time. This information eases the optimal charging scheduling in following MTUs.
7) A contractual connection between the CStO and the CSP is mandatory for the necessary agreement on the financial and legal terms of the CS management.
8) A contractual connection between the EMSP with all the CSP related stakeholder (CStO, EVU, EFU) is necessary in order to provider the User Interface of the Charging Services with all the suitable tools for each one (Web Management Portal, User Mobile Application etc.).

II.2.2. Stakeholders Relations

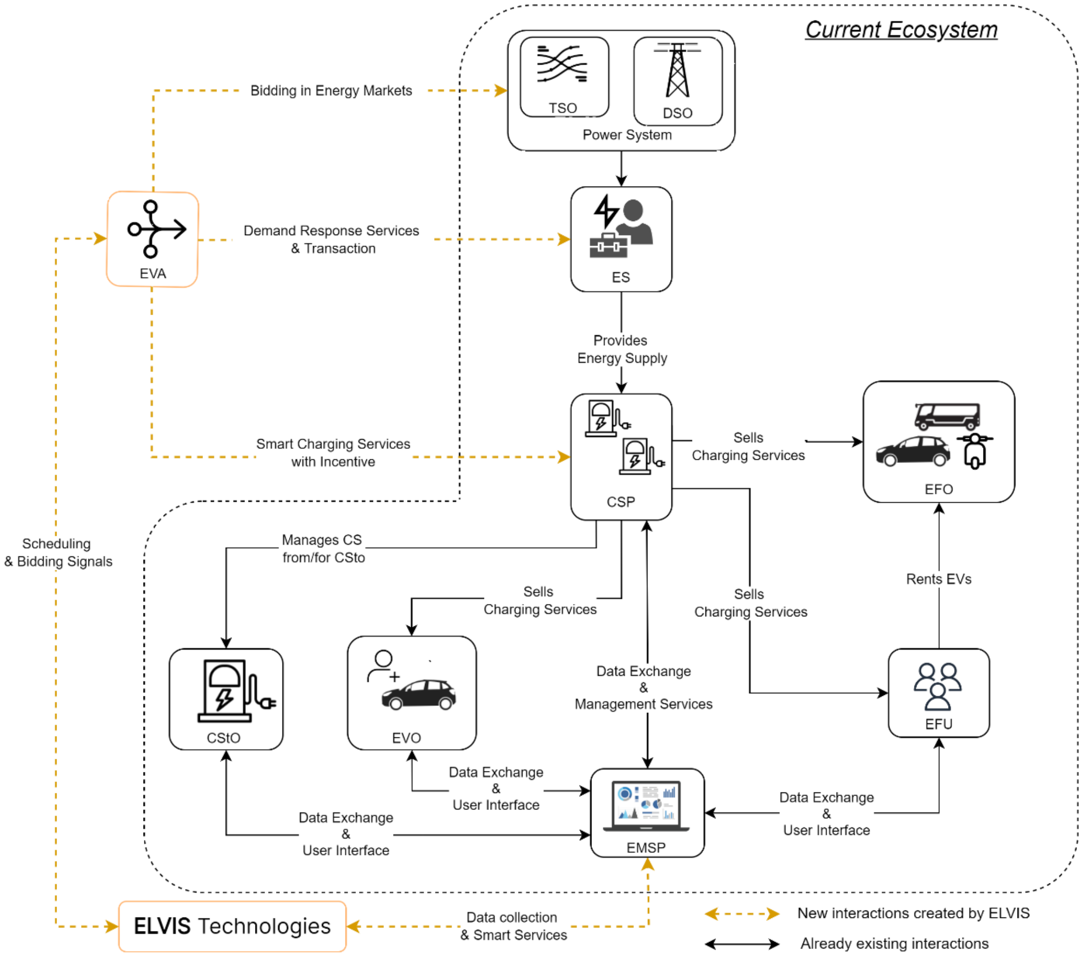


Figure 5 Stakeholders Interactions Overview

In **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.** a high-level Stakeholder interaction review is presented. starting from top left of **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**, the interactions between the stakeholders go as follows:

1) The EVA interacts with the flexibility markets of the TSO and the DSO, in order to provide ancillary services to the grid. It also interacts with the ES to provide DR and/or internal portfolio imbalance reduction services.
2) The ES interacts with the wholesale energy market to buy energy which sells to the CSP.
3) The CSP interacts with the EVUs (EVOs and EFU) via the EMSP in order to provide charging services of the available CSs. The CSP also interacts with the ES for energy supply and with CStO and EFO providing the management of the CSs. Finally, The CSP interacts with the EVA in order to be informed about a bigger picture of the charging network and receive services like smart charging scheduling or optimal participation to the energy markets.

4) The EMSP interacts with the CSP to provide management platforms to handle invoicing, availability, maintenance and in some cases load and number of sessions predictions etc. The EMSP also interacts with the EVUs (EVOs and EFUs) in order to provide services like indication of available charging stations, pricing of charging stations, routing towards a selected charging station, easy payment methods and sometimes initiatives like financial incentives for using a specific charging station etc. Finally, the EMSP interacts with CStO to provide useful data about their CSs (e.g., income, expected income, number of charging sessions per day etc.).
5) Elvis Solutions come to this figure as interactive with the EMSP and the EVA. ELVIS aims to offer smart services to these two actors by providing sophisticated algorithms based on the CSs' data and the market's indications for smart charging scheduling, optimized participation to the energy market, and a secure infrastructure for clearing the networks payments and invoices. ELVIS Technologies can be seen as a plugin system to the current e-mobility ecosystem enhancing the opportunities for a cost-effective charging and grid services provision.

III. Technical Infrastructure

III.1. Power System

Power system is a complex system that consists of many interconnected networks composed of generators, transformer substations, transformers, cables, generators, and consumers. In Figure 6 an overview of the power system components is presented.

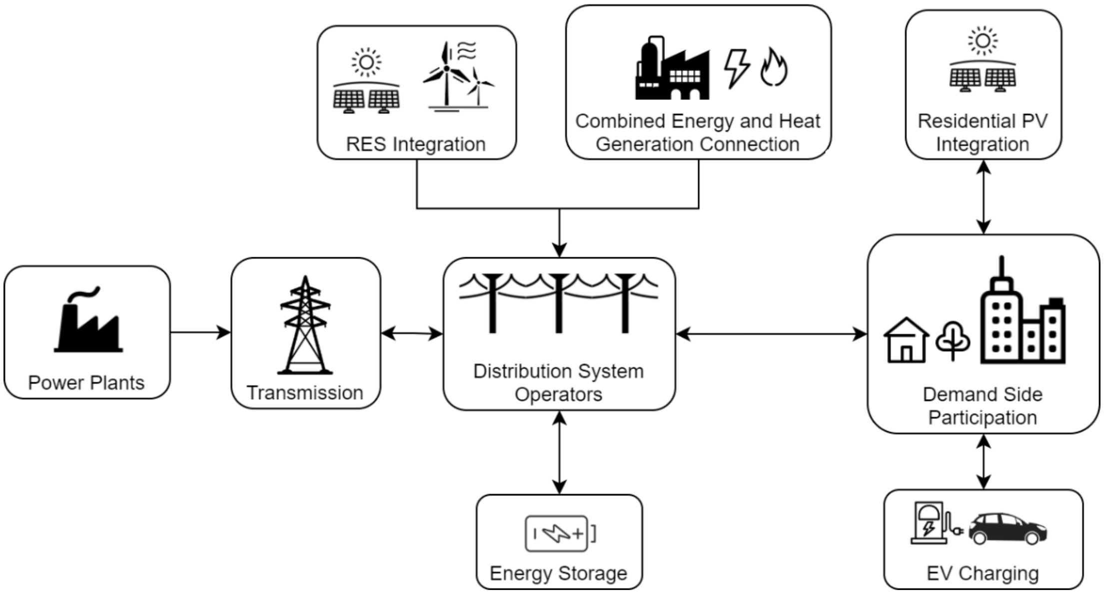


Figure 6 Power System Overview

In principle, an electrical grid is an interconnected network for electricity delivery from producers to consumers. Grids are usually synchronous, meaning that all distribution areas operate with synchronized three phase alternating current (AC) frequencies. This allows transmission of AC power throughout the area, connecting electricity generators with consumers and enabling more efficient electricity markets and redundant generation.

Traditionally, electricity was transported from large power plants via ultra-high and high voltage lines over long distances, to individual grid areas and end-consumers. However, the power grid operation characteristics have been changed recently, adapting to the high penetration of distributed resources, and especially distributed renewable energy stations. Thus, bidirectional power flows are now a common phenomenon in power grids.

Furthermore, demand response is being introduced lately which refers to a grid management technique in which retail or wholesale customers are requested or incentivized to reduce or increase their load based on the market's indications. Such an action can be executed automatically or manually. Currently, TSOs use demand response to request load reduction from major energy users such as industrial plants. Nevertheless, the introduction of implicit demand response promoted by smart metering and explicit demand response like the smart charging case in ELVIS project can encourage customers to charge when electricity is cheaper, by responding to variable price signals.

The following indications focus on the region of Europe and more specifically in Greece, since the ELVIS Project will be developed and tested in Greece, under EU standards and regulations. Transmission networks can vary significantly between different regions. In particular, European countries designed their electricity supply grid to meet primarily their own needs, with limited cross-border energy exchange capacity (EASAC, 2009). Similarly, the distribution grids in a global scale vary a lot regarding the voltage levels utilization as well as frequency used to distribute electrical power to each country's consumers. Specifically in Europe, Transmission lines are mostly functioning with high-voltage (110 - 750 kV), three-phase alternating current (AC). In some cases, high-voltage direct-current (HVDC) technologies are also utilized to provide higher efficiency in long distances (typically greater than 600 km). Electric power distribution carries electricity at a medium voltage from the transmission system to the final customers (often less than 33 kV) (European Commission, 2018). Finally, the Greek national grid is constructed with the following specifications:

1. Ultra-high voltage: 400kV DC, 400kV AC @ 50Hz: Transmission network.
2. High voltage: 150/66kV AC @ 50Hz: Supply of big cities, districts, and industry.
3. Medium voltage: 20 kV @ 50Hz: Distribution grid. Smaller cities and industrial areas.
4. Low voltage: 230 V 1 phase, or 400 V 3 phase @ 50Hz: Supply to end consumers (e.g., households, charging stations, commercial operations).

III.2. Charging Stations

A Charging Station (CS), also called Electric Vehicle Supply Equipment (EVSE), is an electric equipment that supplies electric energy to plug-in EVs including cars, fleet electric vehicles, trucks, buses etc.

The types of Charging are:

1. Trickle Charging (Level 1), the slowest type of charging, this is best reserved for long overnight charges at home and is either provided safely by de-rated dedicated charge stations, or through a standard 3 pin plug, which lacks certain safety features.
2. Slow Charging (Level 2), a better option for home charging, this allows for both top up and overnight charging through a dedicated CS. The 3.7kW
3. Fast Charging (Level 2), Ideal for top up charging, most fast charge stations offer 7-22kW. Typically found in homes, workplaces and in public car parks where people typically spend circa 40 mins or more.
4. Rapid Charging (Level 3), typically used for en-route charging on long distance journeys, rapid chargers can also be used as occasional "caught short" chargers, particularly if available somewhere convenient, e.g., a supermarket. Rapid charging takes place from 43kW power and above. Maximum charging speed may be limited by a vehicle's onboard charger.

There are also three levels of EV charging: Level 1, Level 2, and Level 3. The higher the level of charging, the faster the charging process, as more power is delivered to the vehicle. It's important to note that different EVs charge at different speeds on each level, because each EV can accept different levels of power.

The EV always determines how much power it accept. The EV will not allow the charger to feed the battery with excessive power. The three standard levels are:

III.2.1. Level 1

- Power range: 3.7 kW or less
- Charging: 120-Volt
- Connectors Used: J1772, Tesla
- Charging Speed: 3 to 5 Miles Per Hour
- Locations: Home, Workplace & Public

Level 1 charging uses a common 120-volt household outlet. Every EV can be charged on Level 1 by plugging the charging equipment into a regular wall outlet. Level 1 is the slowest way to charge an EV. It adds between 3 and 5 miles of range per hour.

III.2.2. Level 2

- Power range: 7 to 22 kW
- Charging: 208-Volt to 240-Volt
- Connectors Used: J1772, Tesla
- Charging Speed: 12 to 80 Miles Per Hour
- Locations: Home, Workplace & Public

Level 2 charging is the most used level for daily EV charging. The equipment for Level 2 charging can be installed at home, at the workplace, or in public locations like shopping malls, train stations and other destinations. Level 2 charging can replenish between 12 and 80 miles of range per hour, depending on the power output of the Level 2 charger, and the EV's maximum charge capability.

Most EV owners choose to install Level 2 charging equipment at their residence, because it charges the vehicle up to 10 times faster than Level 1 charging. Charging from a Level 2 source usually means the vehicle will be completely charged overnight, even if you plugged with a nearly empty battery.

Level 2 chargers can deliver up to 80 amps of power. But that requires a 100-amp 208-240V dedicated circuit and a heavy, costly supply line from the breaker box. Most owners will be well served choosing a 40-amp charger that can deliver 9.6 kW to the EV. A 48-amp charger can charge slightly faster at 11.5 kW but requires a heavier gauge wire and the charger must be hardwired to comply with the NEC code. Therefore, 48-amp chargers can cost significantly more than a 40-amp unit and offer only marginally faster charging.

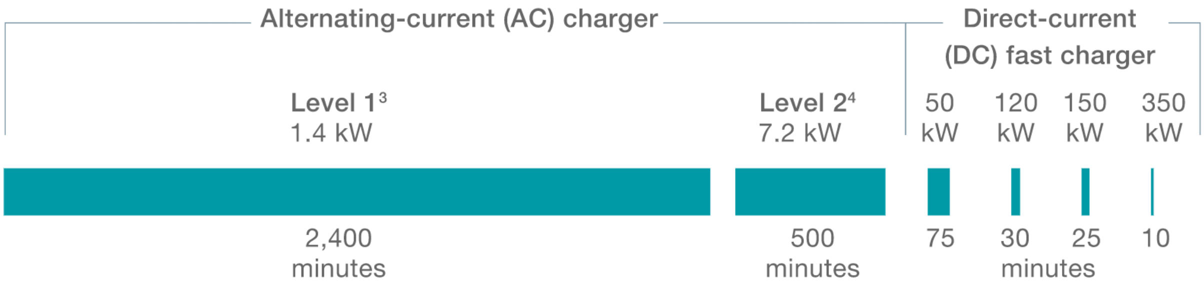
III.2.3. Level 3

- Power range: 50 to 150 kW
- Charging: 400-Volt to 900-Volt (DC Fast Charge & Supercharging)
- Connectors Used: Combined Charging System (CCS), CHAdeMO, Tesla
- Charging Speed: 3 to 20 Miles Per Minute
- Locations: Public

Level 3 charging is the fastest available and can recharge an EV at a rate of 3 to 20 miles of range per minute. Unlike Level 1 and Level 2, Level 3 charging uses direct current (DC). The voltage is between 400 and 900 Volts, which is why they are not installed at homes. Very few residential locations have the high-voltage supply that is required for level 3 charging.

Additionally, DC Fast Chargers cost tens of thousands of Euros. So even if a residence has 400-volt electricity service, the cost to install the CS would most likely cost more than the EV itself. Tesla calls their Level 3 chargers Superchargers; others are called DC Fast Chargers.

Time to “fill up” a 60-kWh electric-vehicle (EV)[1] battery using different chargers[2]



[1] This assumes that the EV can charge at the higher kW direct-current fast-charging stations; most EVs today cannot charge faster than 100 kW.

[2] This assumes that the EV can charge at maximum speed during the entire charge. In reality, the charging speed varies.

[3] Level 1 equipment provides charging through a 120-volt AC plug; it generally refers to a household outlet.

[4] Level 2 equipment provides charging through a 240-volt AC plug and ranges from 16 to 40 amps. The most common is the 240-volt, 30-amp charger, which is 7.2 kW.

Figure 7 Time Need between Different types of Chargers (How battery storage can help charge the electric-vehicle market)

III.3. Charging Station Connectors

The different types of connectors can be roughly divided according to the region where they are most used. AC charging stations usually do not have an integrated charging cable, so the EVU carries the cable that fits his EV, therefore the problem with the types of connectors is basically eliminated. DC fast charging stations always have a cable attached because of security reasons, the high current, cable's cost and weight, thus it is necessary for the EVU to select a station that has the appropriate connector.

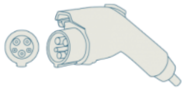
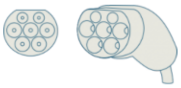
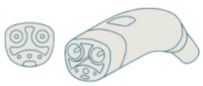
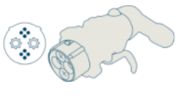
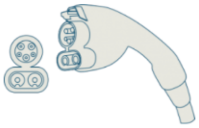
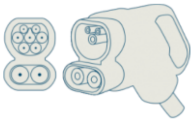
Current type and plug name	**Region**				
	Japan	**America**	**Europe**	**China**	**America / Japan**
AC					
Plug name	Type 1 – J1772	Type 1 – J1772	Mennekes – Type 2	GB/T	TESLA
DC					
Plug name	CHAdeMO	CCS – Type 1	CCS – Type 2	GB/T	TESLA

Figure 8 Charging Station Connectors

III.3.1. Type 1 – SAE J1772

This connector is the industry standard for all EVs performing Level 1 or Level 2 charging. In California, a square plug named J1772 was introduced in 2001, but it was only capable of 6.6 kW, and so in 2008 Yazaki designed a new plug with a power of 19.2 kW, which since 2010 has become the standard for all American vehicles.

III.3.2. CHAdeMO

This is the first of three types of connectors currently present on EVs and first introduced. Originally it was implemented to be the industry standard, developed through the collaboration of five different Japanese automakers. As a result, the CHAdeMO connector remains affluent in Japan and on EVs from Japanese manufacturers. This includes automakers such as Toyota, Mitsubishi, Subaru, and Nissan.

III.3.3. Mennekes – Type 2

The IEC 62196 Type 2 connector (often referred to as Mennekes in reference to the company that originated the design) is used for charging electric cars, mainly within Europe. The connector is circular in shape, with a flattened top edge and originally specified for charging battery electric vehicles at 3–50 kilowatts, with a plug modified by Tesla capable of outputting 150 kilowatts. Electric power is provided as single-phase or three-phase alternating current [AC], or direct current [DC]. In January 2013, the Mennekes - Type 2 connector was selected by the European Commission as official charging plug within the European Union. It has since been adopted as the recommended connector in some countries outside of Europe, including New Zealand (New Zealand's Transport Agency).

III.3.4. CCS – Type 1 & Type 2

Shortly after the CHAdeMO was introduced, a second connector called the Combined Charging System (CCS) was implemented as an additional charging standard, uses the Combo 1 and Combo 2 connectors to provide power at up to 350 kilowatts. These two connectors are extensions of the IEC 62196 Type 1 and Type 2 connectors, with two additional direct current (DC) contacts to allow high-power DC fast charging. Where CCS connectors differ from CHAdeMO, is that they allow for AC/DC charging on the same port. CHAdeMO-equipped EVs require an additional J1772 connector cord to achieve Level 1 or 2 charging.

III.3.5. GB / T standard

In China, the GB / T plug was developed, and currently it is the only one that is used. The fact that there are no other types of connectors in the whole country that would compete facilitates the development of the charging infrastructure. It should be noted that China is the country with the densest network of CSs and has the largest number of EVs in the world. At first glance, the connector seems to be the same as Type 2, but the cables inside are arranged in reverse order so they are not compatible.

III.3.6. Tesla

Tesla allows its customers to charge on their own charging stations that cannot be used by any other vehicle. At the same time, however, Tesla also offers adapters for other types of plugs, so for their vehicles it is not a problem to use the charging stations with a Type 1 or CHAdeMO plug. This proprietary connector exists on all Tesla models in North America, although it does offer CHAdeMO and CCS adapter for certain markets. For example, its Model 3 was built with a CCS connector for Europe. Furthermore, older European Teslas were retrofitted with adapters to support the existing connector plus the standard CCS type 2. This helped Tesla owners utilize the growing charger network overseas.

Nevertheless, each connector can be easily transformed from one type to another with the use of an adaptor. Adaptors can be found in the market in low prices, making the procedure of changing connectors' type easy and affordable.

III.4. Electric Vehicles

Electric Vehicles (EVs), also known as Electric Drive Vehicles (EDVs), describe vehicles that share one major characteristic: the installation of one or more electric motors in the vehicle's powertrain for its propulsion. Such types of vehicles are

1. Battery Electric Vehicle (BEV), a vehicle that runs purely on electric power, stored in an on-board battery that is charged from electricity (typically at a dedicated charge point),
2. Plug-in hybrid electric vehicle (PHEV), a vehicle with a combination of a traditional internal combustion engine and a rechargeable battery, allowing for either pure electric-powered driving or extended range from a combination of the combustion engine and electric motor,
3. Range Extended Electric Vehicles (REEVs, also found as Extended Range Electric Vehicles - EREV), an EV that has only an electric drivetrain, but a small petrol generator to charge the battery when range is depleted for longer trips. Often considered a type of PHEV, and
4. Plug-in vehicle (PiV), a blanket term for any vehicle with a plug socket, including BEVs, REEVs and PHEVs,
5. Fuel Cell Electric Vehicles (FCEVs), This term refers to an EV which uses a hydrogen fuel cell to power its electric motor. The fuel cell creates the electricity to power the car.

The focus of ELVIS is on any type of PiVs, since each EV connected to a CS can be controlled during the charging session (given the suitable protocols like OCPP) and provide flexibility to the TSOs/DSOs. However, the various types of PiVs might provide different profit opportunities highly dependent of the actual charging needs (kWh). Thus, smart charging of BEVs is expected more profitable than other types of PiVs, but these analyses will be part of another ELVIS deliverable.

III.5. Roaming service

EV charging roaming services are analogous to cellular network roaming, CSPs or EMSPs offers the ability for a customer to automatically use the charging infrastructure, and access other services, when travelling outside the geographical coverage area of the charging network, by means of using a visited network. Using roaming CSPs attract more users, more transactions, therefore more income. Meanwhile, EVUs get an improved experience with access to charging stations across service provider borders.

EV roaming is an outcome of the cooperation of electric vehicle CSPs. To provide their customers with the optimal user experience, CPs cooperate and create a roaming network. As the sales of EVs continue to rapidly increase, EV roaming ensures that CSPs can handle the ongoing EV market growth. In this matter, EV Roaming Foundation is developing and maintains the Open Charge Point Interface protocol (OCPI) as free, reliable standard, to ensure a smooth transition to roaming services by every CSP worldwide.

For an EVU, roaming offers the opportunity to use various charging stations even if the EVU is only a customer of one CSP. Roaming networks open up access to thousands of charging stations, all around the world. EVUs are offered with consistent and hassle-free charging experience no matter where they drive.

III.5.1. Different types of EV Roaming

Roaming networks contain multiple layers that can help the SCPs determine the extent of their roaming contract. The first layer includes the charging network of a specific SCP. Outside the CSP's network, there is usually wider charging network. A customer, registered to one's CSPs service, has access to the charging networks of other CSPs and vice versa. These internal roaming stations are available for EV drivers without extra contracts or registration.

The third layer is created by larger roaming networks. These can be based on either generic hubs or bilateral roaming agreements. For example, Europe's biggest international roaming platform Hubject (Hubject, n.d.), enables access to more than 160,000 roaming charging points in Europe, the US, and Japan.

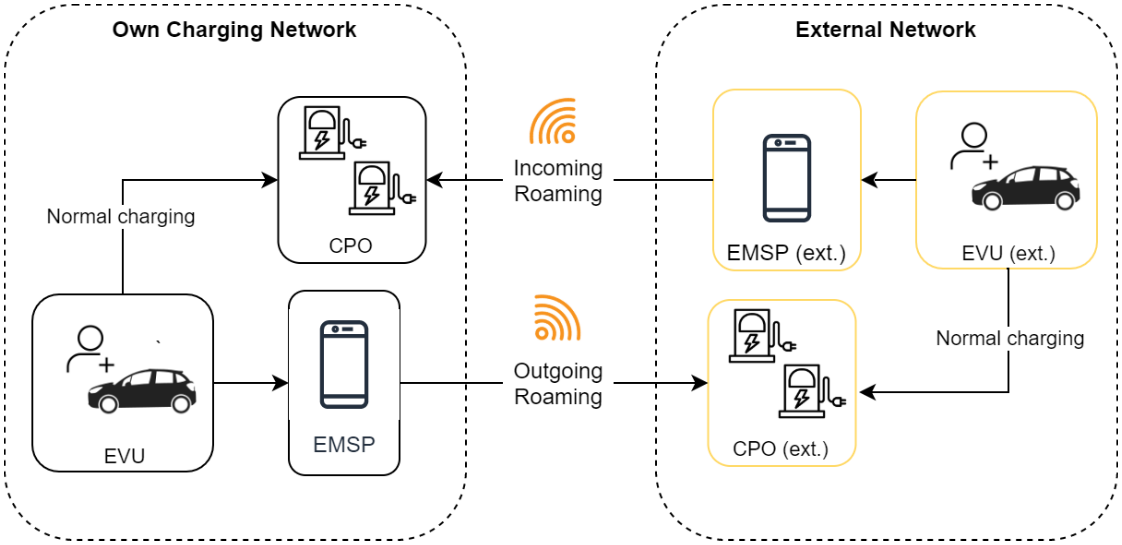


Figure 9 Roaming Overview

IV. EV Charging Industry Standards and Protocols

CSPs and EMSPs are facing challenges expanding internationally especially in dealing with different protocols, regulations, and multi-currencies, and integrating roaming capabilities into their networks. Below, we list the key EV charging industry standards and protocols, which deliver the flexibility that is needed for the entire EV market and will be a key enabler of future EV charging infrastructure developments.

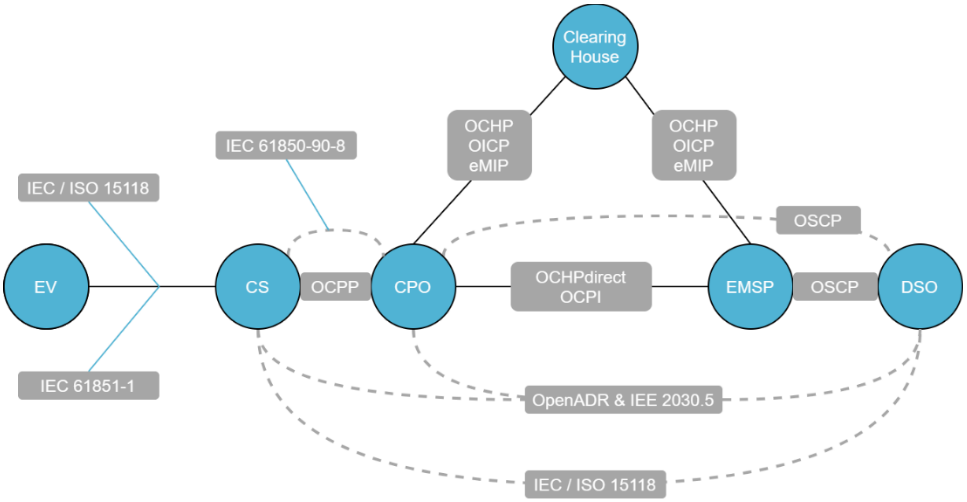


Figure 10 EV charging industry standards and protocols overview (IRENA, 2019)

IV.1. Open Automated Demand Response (OpenADR)

OpenADR is an open and secured foundation for interoperable information exchange to facilitate automated demand response. It is typically used to send information and signals between distribution system operators (DSOs), utilities and energy management and control systems to balance energy demand during peak times. OpenADR 2.0 enables standardization of demand response (DR) and distributed energy resources (DER) communications and automated DR/DER processes. It also simplifies customer energy management and eliminates stranded assets.

IV.2. Open Smart Charging Protocol (OSCP)

OSCP is an open protocol for communications between a charge point management system and an energy management system of a site owner or a DSO system. The protocol can be used to communicate a real-time prediction of the local electricity grid capacity to the charge point operator. OSCP facilitates capacity-based smart charging of EVs.

IV.3. Open Charge Point Protocol (OCPP)

The Open Charge Point Protocol (OCPP) is an application protocol for communication between EVs charging stations and a central management system. It is an international, open-source, vendor-independent standard which is available for free. The protocol was developed by the Open Charge Alliance (OCA) for the EV infrastructure market and is considered the de-facto standard for charging infrastructure interoperability among charging equipment manufacturers, software and systems providers, charging network operators and research organizations. The protocol is a proven way to optimize the cost and minimize the risk of networked infrastructure investments. It provides flexibility for infrastructure operators to be EVSE-agnostic and allows easy access for EV drivers. The latest version, OCPP 2.0, has a lot of new and improved features for device management, transaction handling, security, smart charging functionalities, support for display and messaging and many additional improvements requested by the EV charging community. OCPP 2.0 also introduced the option to support "plug and charge" functionality for EV supporting the ISO 15118 protocol, since September 2020 this feature has also been added to OCPP 1.6. (Using ISO 15118 Plug & Charge with OCPP 1.6, 2020)

IV.4. ISO 15118

So along with EVs their communication with the CS has to be considered. ISO 15118 –an international standard for bi-directional digital communications between electric vehicles and the charging station. ISO 15118 (also referred to as "OpenV2G") defines a V2G communication interface for bi-directional charging/discharging of electric vehicles. ISO 15118 is a key enabler of the Plug & Charge capability, allowing EV drivers to insert the charge plug into the car, charge, and drive away when ready. This process is enabled by a digital certificate located in the vehicle, allowing it to communicate with the charging point management system (CPMS). This enables a seamless end-to-end charging process, which includes automatic authentication and billing, and avoids the need to use an RFID card, an app or to memorize PIN numbers.

Most CSs either run on OCPP 1.5 or OCPP 1.6. However, the latest version of OCPP 2.0 provides a significant improvement that allows sending the requested energy demand from the CS to the management system. The Smart Charging functionality uses this precise and accurate information to plan the charging event correctly.

IV.5. eMobility Interoperation Protocol (eMIP)

The eMIP, is provided by GIREVE as part of his main business objective: "open access to vehicle charging stations". In this current version, eMIP targets two goals: • Enabling roaming of charging services by providing a charge authorization and a data clearing house API. • Providing access to a comprehensive charging point database.

IV.6. Open InterCharge Protocol (OICP)

The Open InterCharge Protocol (OICP) is the most widely implemented communication standard between EMSP and CPO systems. The information exchange is in most cases based on contractual relationships between EMSPs and CPOs. In these cases, Hubject only processes service requests in case there is a valid contract for the requested service. How EMPs and CPOs manage their service contracts is out of the scope of this document because the contract management aspects of the platform are conducted via a GUI-based system component (Hubject, 2019).

IV.7. Open Charge Point Interface (OCPI)

The Open Charge Point Interface (OCPI, 2020) enables a scalable, automated EV roaming setup between Charge Point Operators and eMobility Service Providers. It supports authorization, charge point information exchange (including live status updates and transaction events), charge detail record exchange, remote charge point commands and the exchange of smart-charging related information between parties. It offers market participants in EV an attractive and scalable solution for (international) roaming between networks, avoiding the costs and innovation-limiting complexities involved with today's non-automated solutions or with central roaming hubs. As such it helps to enable EV drivers to charge everywhere in a fully informed way, helps the market to develop quickly and helps market players to execute their business models in the best way.

V. ELVIS Platform Specifications

V.1. High Level Architecture

The envisioned integrated solutions are nevertheless technically challenging, mainly due to the large number of stakeholders and entities that are involved and need to interoperate to some or to large extent. CSs, EVs, EVUs, the Marker Operator and the System and/or Network Operators are the most relevant ones. For the successful coordination of the above parties, an intermediate entity, the Electric Vehicle Aggregator (EVA) has been recently proposed (Bessa & Matos, 2010) to act as the intermediate player (CSP) that optimally operates the smart charging of large EV fleets and optimally interacts with all the involved stakeholders.

However, EVA's market participation to be successful should be fully compliant with the given market design for electricity. Under the pan-European market provisions ((Amini, Karfarian, & Karabasoglou, 2016), (Li, Huang, & Zhang, 2018)), electricity is traded in various short-term markets, namely the Day-Ahead Market (DAM), the Intra-Day Market (IDM) and the Balancing Market (BM), with the Greek electricity market being also under a structural reform ((RAE, 2018), (IPTO, 2019)) to comply with the pan-European model. To sum up, in Figure 11, a representation of the core EVA operations and interactions is presented, clearly showing its complex role as a middleman between EVs, CSs and EVUs from the one side and the Market Operator and the System Operator from the other side. Optimal market participation strategies for EVAs have been proposed in the bibliography (e.g. (Hoogvliet, Litjens, & Van Sark, 2017), (Alipour, Mohammadi-Ivatloo, Moradi-Dalvand, & Zare, 2017)) however, they are limited in considering only a single market and they are not able to model the sequential participation in DAM, IDM and BM, which is the real-world case. Finally, since market-based smart charging is in its early phase, an ongoing discussion of the most suitable business models is still open. Several business models have been proposed and new ones emerge, offering a wide variety of contractual, financial and technical relationships between the involved stakeholders (Electrific, a European Union's Horizon 2020 Project, 2020), which should be clearly defined in each case.

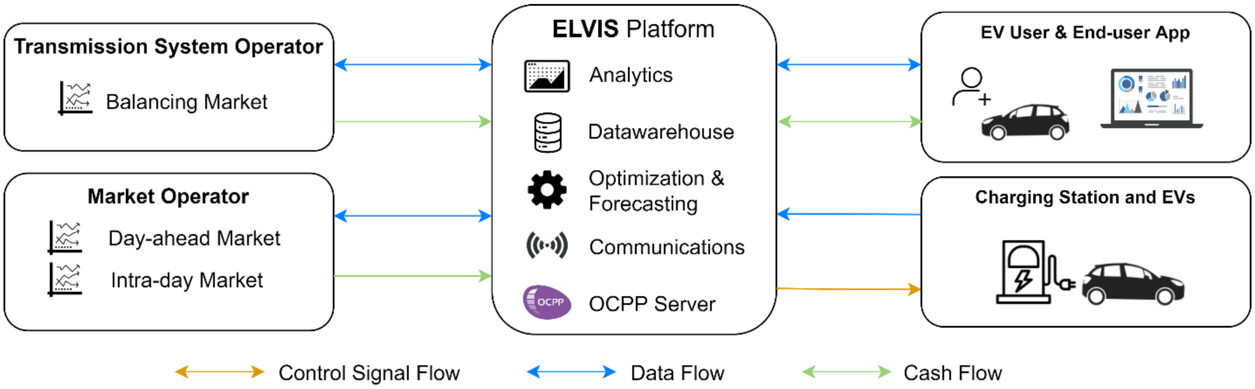


Figure 11 ELVIS Platform Overview

V.2. ELVIS Platform Components

V.2.1. Components Overview

The purpose of this section is to describe all the different components of the ELVIS Platform. Each section presents the technical specification and characteristics of each of the platform's component and describes the main concepts of their implementation. Figure 2 presents the platform's overview with all the relations between its components.

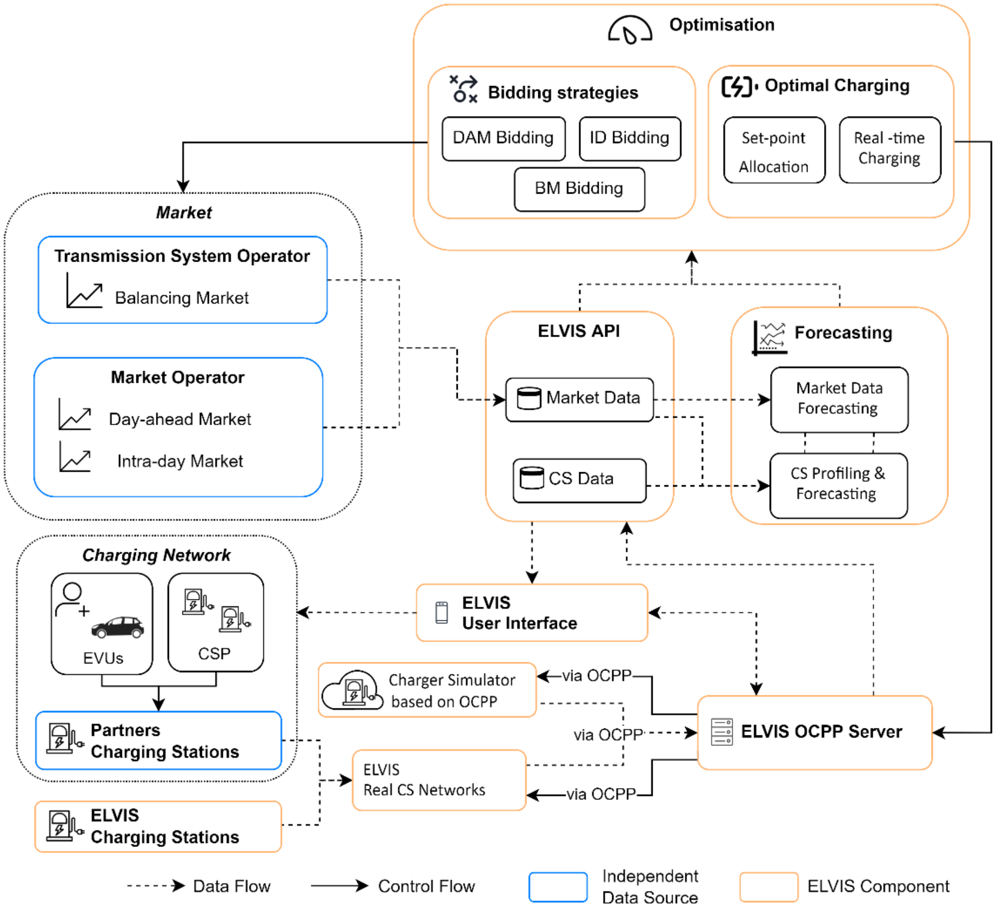


Figure 12 ELVIS Platform Technical Overview

V.2.1.1. Storage of Market Data

Real market data coming from the Market and System Operators will be initially integrated as historical information and a dedicated parsing software tool will be deployed as polling mechanism to fetch new market data through reliable and publicly available APIs in real-time. The integrated data from the aforementioned procedure will be stored in dedicated databases with the appropriate relations between each data point. These data points combined with their relations can be play a crucial role in the market understanding, representation and as a result it's forecasting, that it will be described in section V.3.2.

V.2.1.2. Storage of CS Data

Historical and real-time CS data offered by the real CS networks will be also gathered and stored in ELVIS Platform. Storage of the collected data will be employed in database that is ideal for handling both historical and real-time data. Real-time fetching of CS data will be decided through direct interaction with the partnered main stakeholders.

V.2.2. Forecasting

V.2.2.1. CS Profiling and Forecasting

Forecasting algorithms will be deployed to model the CSs load profiling, and the impact of exogenous variables like meteorological conditions and seasonal variables like weekends, summer/winter period, public holidays, market operational data and others. All forecasting methodologies and options available will be considered including innovative forecasting tools. Machine learning models, Neural Networks and Deep Learning models will also be developed and examined for the prediction of the expected CSs load. Multiple configurations and architectures will be tested utilizing open-source and publicly available meta-learner tuners. The tools will provide updated online CSs load predictions to incorporate CS conditions, along with latest weather conditions and predictions. The uncertainty around the provided forecast will also be evaluated using probability analysis theory and applied techniques. Finally, the forecasting tool performance will be evaluated with the CS data offered by the real CS networks of ELVIS partners, while the tool performance in the two different cases will also be evaluated.

V.2.2.2. Market Data Forecasting

The Market data forecast can be approached with two main methodologies.

The first methodology that will be examined is through machine learning algorithms that will be deployed to model and forecast key market-related variables (e.g., prices, balancing activation estimation, etc.). First, naïve models can be deployed, considering past data as the forecast, assuming that the market has a constant and steady operation. Naïve methods can be enhanced by seasonal components or weather-related formulas. Stepping forward more sophisticated models can be examined depending on the variable that needs to be forecasted. Regression or classification methods and models can be deployed to assert each problem at a time.

These forecasts will expand to a pre-defined look-ahead horizon and will be frequently updated based on the specific business model needs. The updated forecasts will feed the optimization models of the developed bidding strategies in the various markets (DAM, IM, BM) of the emerging pan-European market design.

V.2.3. Optimization

V.2.3.1. Bidding Strategies (Retailer, Aggregator, Both)

In this task several mathematical models will be developed to address the challenge of optimal bidding strategy of the EVA in EU-based markets. The models will be formulated as stochastic linear and mixed-integer linear programs and will be solved sequentially (i.e., the market schedule of one market will be the model input for the next market). The bidding model for DAM will be solved once per day, for IDM thrice per day (three discrete auctions) and every hour for the continuous intra-day market. Extra emphasis will be given to the Balancing Market (BM) bidding model, which will be solved intra-hourly to optimize balancing services provision and maximize revenue streams. (A, S, & B, 2015).

V.2.3.2. Charging Setpoint Allocation

Finally, the models for optimal charging set-point allocation to the CSs, previously developed in (Vagropoulos, Kyriazidis, & Bakirtzis, Real-time charging management framework for electric vehicle aggregators in a market environment, 2016), will be enhanced and will be integrated into the platform for real-time operation. The models will be fed in real-time with balancing activation commands, the EVA latest market schedules and CS data and will produce new charging set-points at a predefined period (i.e., 4 sec) for charging modulation of connected EVs.

V.2.4. End-user Application and CS administrator Dashboard (EMSPs Reservation/Billing)

Two user-friendly interfaces will be developed in ELVIS targeting EV users and CS administrators accordingly. More specifically, a dedicated smartphone application will be developed to provide ELVIS end-users with real-time information about CS availability-reservations, charging cost, expected time till charge is completed, etc. The CS management dashboard will visualize both historical and real-time information about CS availability/reservations, individual meter data, energy costs, etc. across all managed CSs.

V.2.4.1. ELVIS Mobile Application

The ELVIS mobile application will be the main interaction point between the ELVIS Platform and the EVUs. It will offer an interface where the EVUs will be able to reserve a CS for a future charging session or choose a dynamic pricing charge depending on the chargers' and market's dynamics at each moment. From the EV user's perspective, a registration form will be embedded as the initial step of using the application. Necessary information for the user creation such as name, email, password, EV brand will be required. As shown on Figure 13 on the left, a list of nearby CSs will be presented to the user along with their geographic locations visualized on a map. In addition, information about the neighboring available CSs will be included, such as the ability to support fast charging, the number of available charging connectors. Another key functionality of the ELVIS mobile application is the reservation feature that will be used to schedule a future charging session by guaranteeing the availability of the CS at the given moment. Lastly, during the charging session the mobile app will visualize real-time charging data as shown on the right in Figure 13.

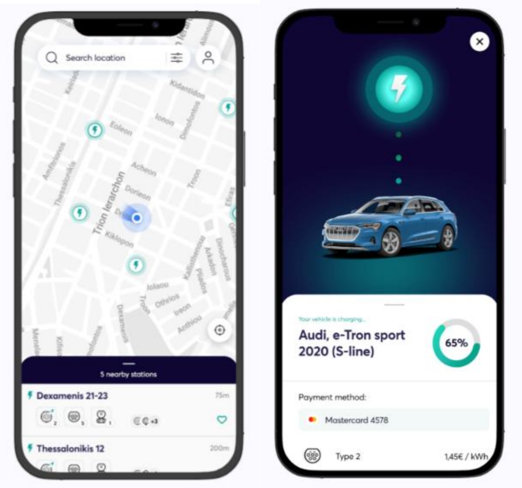
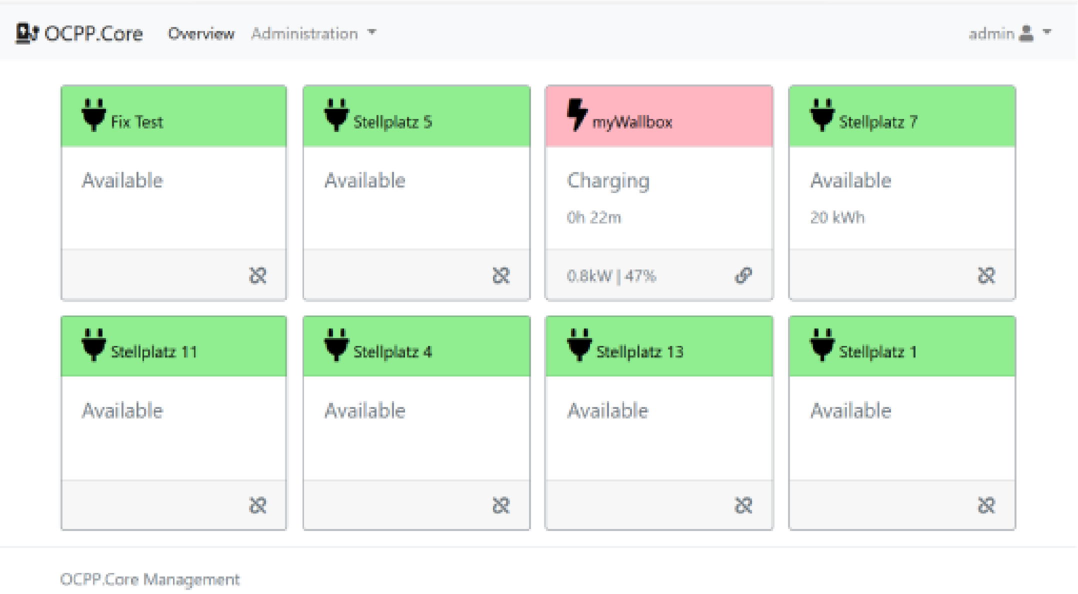


Figure 13 Indicative screenshots of the functionalities envisioned for the ELVIS mobile app based on the (Carge App, 2021)

V.2.4.2. ELVIS CS Management Dashboard

The ELVIS CS administrator dashboard will be the main interaction point between the ELVIS Platform and the CS administrators. Having examined the open-source available CS management dashboards, the one offered by OCPP core is considered as an ideal starting step for developing the ELVIS envisioned functionalities.

The proposed administration dashboard will provide information for all the connected CSs, with indicative information being the CS name given during the CS registration, the current CS status (occupied or not) and others. In case of an ongoing charging session, real-time information will be displayed per CS. As shown in Figure 14 Indicative Screenshots of the Functionalities Envisioned for the ELVIS CS Management Dashboard based on the Dashboard Figure 14, the estimated charging duration, along with the real-time charging rate in kW and the battery status in percentage can be displayed.



Fix Test
Available

Stellplatz 5
Available

myWallbox
Charging
0h 22m
0.8kW | 47%

Stellplatz 7
Available
20 kWh

Stellplatz 11
Available

Stellplatz 4
Available

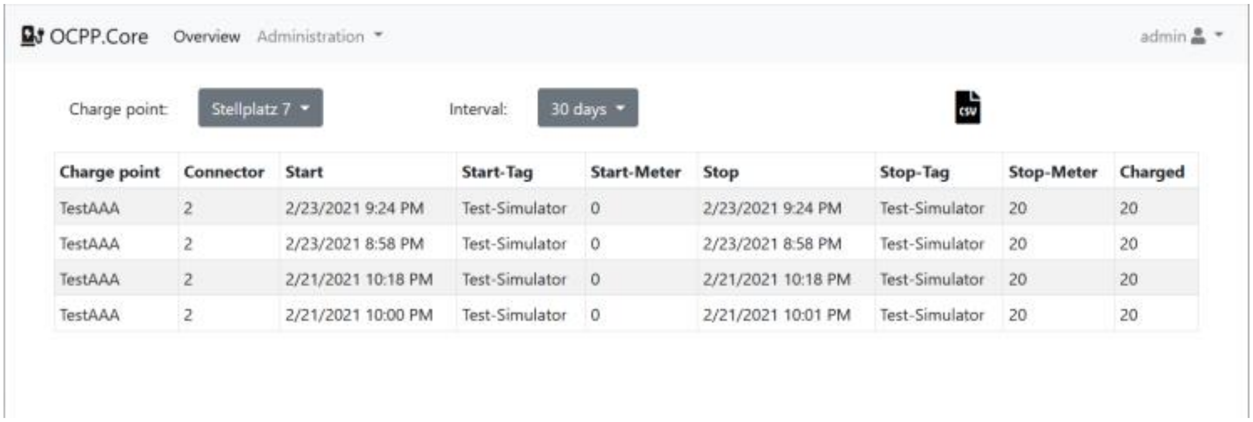
Stellplatz 13
Available

Stellplatz 1
Available

OCPP.Core Management

Figure 14 Indicative Screenshots of the Functionalities Envisioned for the ELVIS CS Management Dashboard based on the (OCPP.Core, 2021) Dashboard

Additionally, the administration dashboard will be able to provide former charging session information (Figure 15) such as the start and stop time and the connector used. Lastly, the charged amount for individual sessions is gathered by subtracting the on-start meter status by the on-completion meter status.



Charge point: Stellplatz 7

Interval: 30 days

Charge point	Connector	Start	Start-Tag	Start-Meter	Stop	Stop-Tag	Stop-Meter	Charged
TestAAA	2	2/23/2021 9:24 PM	Test-Simulator	0	2/23/2021 9:24 PM	Test-Simulator	20	20
TestAAA	2	2/23/2021 8:58 PM	Test-Simulator	0	2/23/2021 8:58 PM	Test-Simulator	20	20
TestAAA	2	2/21/2021 10:18 PM	Test-Simulator	0	2/21/2021 10:18 PM	Test-Simulator	20	20
TestAAA	2	2/21/2021 10:00 PM	Test-Simulator	0	2/21/2021 10:01 PM	Test-Simulator	20	20

Figure 15 ELVIS CS Historical Charging Session based on the (OCPP.Core, 2021) Dashboard

V.2.5. OCPP Server

During ELVIS project, a dedicated OCPP server will be deployed, to act as the underlying infrastructure interconnecting all managed CSs and enabling their remote management and control. The adoption of a management tool will provide the interoperability required for controlling CSs developed by different vendors in a unified way, furthermore the open-source nature of the management tools that will be used offer flexibility to ELVIS team to extend and embrace the existing features of the tools. Core OCPP functionalities (supported by OCPP v1.6 and above) that will be employed through the management tools include a) registration of CSs and EV users, b) monitoring and control of charging transactions-reservations, c) monitoring of CS meter data and d) control of Smart-charging process. Several functions will be extended, to support the envisioned use cases, including the definition of custom charging profiles to match the time varying charging schedules of ELVIS and the extension of monitored CS meter parameters to support power, voltage, and frequency where applicable.

V.2.5.1. OCPP Simulator

The goal of this task is to enable ELVIS platform to register and interact with virtual CSs that follow preconfigured behavior. This step will offer ELVIS the ability to consider large scale scenarios of a much wider CS network than the physically connected one. Behavior of virtual CSs will be configurable, in order to emulate the behavior of real CSs, as captured through the representative data that will be offered by the co-operated organizations. To accomplish this step, we will consider existing OCPP compliant CS simulators (Docile CP Simulato, 2021), (Scriptable OCPP Chargepoint Simulator, 2021), (OCPP-1.6-Chargebox-Simulator, n.d.) that support behavior specification and integrate it with ELVIS. Next, taking as input the CS Data and CS consumption profiles derived through the analysis of [CS Profiling and Forecasting], specific behavior classes will be designed to properly configure the operation of virtual CSs.

V.2.5.2. Real Charger with OCPP

Having established an operational OCPP-based platform enabling management of both real and virtual CSs, the goal of this task is to integrate the real CSs and their meters with the platform. Planned steps include the registration and configuration of physical CSs on the central OCPP server, along with the tuning of monitored parameters and reporting interval. The final step is to verify the successful integration of the physical CSs, by connecting a real EV to monitor that all transaction messages and measurements are properly exchanged with the central OCPP server and also to verify that the charging schedules of ELVIS platform can directly adapt the charging rate of the EV under test.

V.2.6. Smart Contractual Framework

V.2.6.1. Introduction to Blockchain

Management of distributed energy systems will become increasingly complex, dealing with the interconnection of RES, widespread infrastructures, the coordination of distributed facilities, and the protection measures of the power system (Hou, Wang, & Luo, 2020).

Various energy aggregation management technologies emerged at a historical moment, such as micro-grids, virtual grids, and load aggregators. As the intermediate layer between the Independent System Operator and distributed energy, aggregators face many difficulties. The sharing of the power supply and demand information and real-time electricity price is one of them.

The German Energy Agency claims that energy blockchain can improve energy efficiency, accelerate the development of IoT platforms and digital applications, and can make innovation in P2P energy trading and decentralized power generation (Burger, Kuhlmann, & Richard, 2016). According to the reports from (Deloitte, 2016) (IRENA, 2019), the operation of the energy market based on blockchain technology is more transparent and efficient, which can improve competition and promote consumer mobility and the conversion of energy suppliers, and reduce operating costs, increase efficiency, achieve rapid and automated processes.

Decentralized blockchain technology is gradually recognized as a game-changer for everything centralized, including traditional centralized energy. Meanwhile, the energy sector is transitioning from a centralized to a distributed energy resource.

V.2.6.2. An overview of Blockchain - What is blockchain?

Blockchain is a distributed, decentralized, and immutable ledger for recording transactions, tracking assets, and building trust. For a transaction to be recorded in the ledger, the majority of users in the blockchain network must agree and record their agreement. A series of transactions is gathered and assigned to a block in the ledger, which is made up of blocks. Each block includes a timestamp and hash function for the previous block to link them together. The hash function verifies the data inside the block's integrity and non-repudiation. Furthermore, each user of the blockchain network has a copy of the original ledger, and all users are synchronized and updated with new updates to keep everyone up to date (Atlam, Alenezi, Alassafi, & Wills, 2018). The addition of smart contract technology to a blockchain enhances the utility even further and allows for smart energy optimization (Huh & Kim, 2019).

V.2.6.2.a. Hash

A hash is a mathematical function that converts an arbitrary-length input into an encrypted output with a fixed length. As a result, regardless of the initial amount of data or file size involved, its unique hash will always be the same size. The hash function is a concept used to search for data in a database. A hash function must be collision-resistant, meaning that it must be impossible for two separate inputs to yield the same result. As a result, the blocks' hashes are used to identify them, which serves two purposes: identification and integrity verification. Each block has the hash of its parent inside its header, forming a chain that extends back to the beginning. The hash values are stored in a hash table, a well-organized indexing system that improves search performance.

V.2.6.2.b. Asymmetric encryption algorithm

Asymmetric encryption algorithm is the encryption technology used in blockchain technology for security requirements and ownership verification. Compared with symmetric encryption, which uses the same key for encryption and decryption, asymmetric encryption algorithms have higher security due to different coding techniques (Diffie & Hellman, 1976).

The characteristics of an asymmetric encryption algorithm are that the algorithm is more complicated, and the security of the system depends on the algorithm and key. However, because of its complicated algorithm, the speed of asymmetric encryption is not as fast as that of symmetric encryption. There is only one key in a symmetric cryptosystem, and it is private. Asymmetric key systems have two keys, one of which is public. In this way, it is not necessary to pass the secret key simultaneously during the transmission of information, which improves the security of the system.

V.2.6.2.c. Network protocol

A protocol, in computer science, is a set of rules or procedures that regulate the transfer of data between two or more electronic devices. Blockchain network protocols generally adopt the P2P protocol to ensure that each computer in the same network is equal to each other without any special nodes. Due to the lack of a centralized server, P2P network is inherently resistant to attacks and highly fault-tolerant. Each node has equal status in the P2P network, and services are distributed on each node. Therefore, attacks on some nodes or the network have little impact on the entire system. Different blockchain systems develop their P2P network protocols as needed.

V.2.6.2.d. Distributed data storage

The traditional distributed storage system implements a data management mechanism controlled by a central node, while the distributed ledger is based on specific consensus rules and uses multi-party decision-making and standard maintenance for data storage and replication.

Distributed storage means that each participating node has independent and complete data storage. In order to maintain data consistency, data between distributed systems must be synchronized. To alleviate network congestion caused by comparing all data on different machines, the blockchain stores all transactions in the data structure of the Merkle tree. A Merkle Tree is a binary tree consisting of a set of leaf nodes, intermediate nodes, and a root node. This tree-like data structure is very efficient in quickly inducing and verifying the integrity of large-scale data. The Merkel tree is used to summarize all transactions in a block. Its root is the hash value of the entire transaction set. The lowest leaf node is the hash value of the data block.

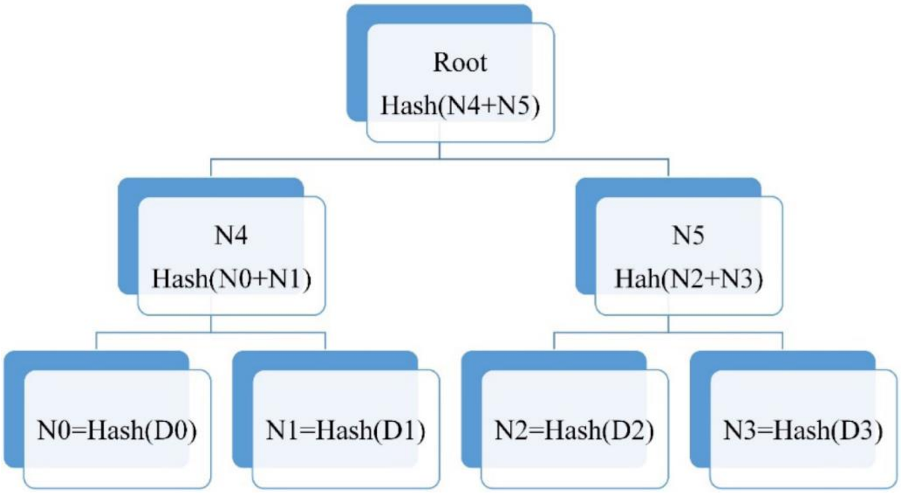


Figure 16 Merkel Tree Structure

Distributed Ledger Technology (DLT) is essentially a decentralized data storage technology that can perform data sharing, synchronization, and replication in a network of multiple network nodes, multiple physical addresses, or multiple organizations. Compared with traditional distributed storage systems, distributed ledger technology has two different characteristics.

V.2.6.2.e. Consensus algorithm

Distributed systems are bound to face consistency problems, and solving consistency problems is called consensus. A consensus algorithm is a process in computer science used to achieve agreement on a single data value among distributed processes or systems. The consensus layer is responsible for ensuring the consistency of data records of all nodes in the entire network. The synchronicity and data consistency make the blockchain system have the characteristics of transparent information and data sharing.

The consensus algorithm usually solves the problem of which node in a distributed system initiates a proposal and how other nodes reach an agreement on this proposal. According to the differences between traditional distributed systems and blockchain systems, consensus algorithms can be divided into two types: consensus algorithms between trusted nodes and consensus algorithms between untrusted nodes.

According to different application scenarios, consensus algorithms can be divided into consensus algorithms that are suitable for public chains, such as PoW (Proof of Work) and PoS (Proof of Stake) and consensus algorithms that suitable for alliance chains or private chains, such as PBFT (Practical Byzantine Fault Tolerance).

Proof of Work mechanism (PoW)

The concept of PoW was first proposed by (Dwork & Naor, 1992). To prevent anyone from gaming the system, proof of work (PoW) demands network members to solve an arbitrary mathematical puzzle. In cryptocurrency mining, proof of work is commonly employed to validate transactions and mine new tokens. The advantage of PoW is that this competitive algorithm mechanism solves the problem of ownership of bookkeeping rights in distributed bookkeeping. The main disadvantages lie in the large amount of waste of resources caused by mining behavior. The long time reaching a consensus makes it difficult to meet commercial applications (Pilkington, 2016).

Proof of Stake mechanism (PoS)

PoS does not require users to find a random number in an unlimited space, and it is a system that provides corresponding interest based on the amount and time the users hold a certain type of digital currency. The PoS mechanism can reduce the mining difficulty of nodes according to the algorithm, speeding up the search for random numbers. The advantage of PoS is that it solves the problem of waste of resources. However, due to the low cost of mining, the possibility of attack is increased. However, nodes in the network still need to perform mining calculations, so applying them to the commercial field is difficult.

Delegated Proof-of-Stake mechanism (DPoS)

DPoS is a new way to protect the cryptocurrency network. This mechanism is similar to a board vote. A holder holds a certain number of nodes, and the agent performs verification and bookkeeping. If these nodes do not fulfill their accounting responsibilities, the network will choose new nodes to replace them. In order to motivate more people to participate in the election, the system will generate a small number of tokens as a reward. The advantage of the DPoS is that it offsets the negative effects of centralization. Each client in the system can choose which node to trust rather than simply trusting the node with the most resources. Secondly, by reducing the requirements for confirmation during the transaction process, the transaction speed in the system has risen linearly. Therefore, more transactions will be accommodated in a single block, thereby minimizing the cost of system operation and maintenance and maximizing the system's efficiency.

Practical Byzantine Fault Tolerance Algorithm mechanism (PBFT)

The PBFT was introduced by (Castro & Liskov, 1999). The PBFT algorithm is robust to survive Byzantine faults in asynchronous contexts and is optimized for fast processing speeds and low latency, making it suitable for everyday use.

The algorithm is applied to a distributed file copy system. There are “3f + 1” replication nodes in the system, of which there are at most “f” Byzantine error nodes. Each replication node in the system runs a copy of the finite state machine and supports several operations. PBFT nodes need only a little time to prove their authenticity, reducing the spread of spam and fake messages among nodes.

V.2.6.3. Different Types of Architectures for Blockchain

A blockchain network can be built in a variety of ways, and they can be public, private, password-protected, or created by a group.

V.2.6.4. Public blockchain networks

Anyone can join and contribute in a public blockchain, such as Bitcoin's. It requires significant computing power, there's little or no privacy for transactions, and security is inadequate. These are critical factors for the industry's blockchain application cases.

V.2.6.4.a. Private blockchain networks

A private blockchain network is a decentralized peer-to-peer network, analogous to a public blockchain network. However, the network is administered by a single organization that decides who is allowed to participate, executes a consensus method, and keeps track of the shared ledger. This can significantly boost participant trust and confidence, depending on the use case. A private blockchain can be used and even hosted on-site within a company's firewall.

V.2.6.4.b. Permissioned blockchain networks

Businesses that develop a private blockchain usually set up a permissioned blockchain network. It's important to note that public blockchain networks can also be permissioned. This restricts who is allowed to use the network and what transactions they can carry out. Participants must first receive an invitation or authorization to participate.

V.2.6.4.c. Consortium blockchains

The maintenance of a blockchain can be shared across multiple companies. Who can submit transactions or access data is determined by these pre-selected organizations. A consortium blockchain is ideal when all members need to be permissioned and share responsibility for the blockchain.

V.2.6.5. Smart contracts

The concept of smart contracts dates back to 1994 and appeared almost simultaneously with the Internet. The smart contract layer is responsible for compiling and deploying the business logic of the blockchain system in code form, completing the condition triggering and automatic execution of the established rules, and minimizing manual intervention. The operating objects of smart contracts are mostly digital assets, and data is difficult to modify after being chained. The strong trigger conditions determine the high value and high risk of using smart contracts. Avoiding risks and exerting value is a difficult point in the current wide-scale application of smart contracts. This is because the smart contract is not only defined by the code, but also enforced by the code, which is completely automatic and cannot be interfered with.

The preset data resources are automatically issued from the smart contract when the conditions are met. The core of the smart contract system is that a set of transactions and events enter the smart contract. The construction and execution of smart contracts based on blockchain include the following steps:

- Construction of smart contracts: Multiple users in the blockchain participate in formulating smart contracts.
- Storage of smart contracts: Smart contracts spread to each node through the P2P network and stored in the blockchain.
- Execution of smart contract: Smart contract regularly checks the status of the automaton to verify the transactions that meet the conditions, and automatically execute and notify users after reaching a consensus.

In order to proceed with Smart Contracts, the following technical requirements must be met. First of all, a smart meter that provides all the necessary information about EV Charging must be installed on each EV Charger in order to track the charging process. Moreover, a HTTP2 network connection between all the different parties that take part in the Charging process must be established to ensure real-time communication amongst them.

Blockchain technology can offer more secure and transparent transactions between the different stakeholders involved in the ELVIS platform.

VI. Business Use Cases

Based on the generic ELVIS vision, several Business Use Cases (BUC) were identified and will be described in this section. The BUCs represent a high-level interaction with the ELVIS overall solution, which also includes business interests like stakeholders' contracts and business models. The BUCs are based on the stakeholders' main goals and comfort. Each BUC reflects one or more benefits for those respective stakeholders, when participating or interacting with the ELVIS solution.

The BUCs for the EVUs, mainly comprise cost reduction from e-mobility and an overall improved experience, including EV attractiveness and EV driving behavior. For the EFO, the essential BUCs within ELVIS cover cost reduction and an increased potential customer base. EFO and CSOs both have the similar BUCs, increasing the potential customer base, adjusting the business model, receiving incentives for participation in ELVIS, achieving full energy supply from renewable sources leading to independence from the grid and usage of smart charging. With potential participation in ELVIS, the DSO could understand the repercussions of e-mobility and could use smart charging for decreasing grid reinforcement costs while securing the grid stability and maximizing utilization of local renewables.

VI.1. BUC-01: Use Smart e-Mobility Services

The main use case of EVUs with the ELVIS platform is the use of smart e-mobility services. The EVUs will be able to interact with an ELVIS software component, the mobile app, in order to enhance their overall charging experience and benefits. The EVUs will be provided with helpful data regarding charging sessions and dynamic pricing opportunities by the ELVIS software.

Stakeholder: EVU (EVO, EFU)

VI.2. BUC-02: Reduce EV Charging Costs

Due to adherence to certain suggestions made by ELVIS, EVUs will be able to reduce their costs for charging their EVs. EVUs will get financially incentivized by ELVIS for adjusting their charging behavior. Different types of incentives may be implemented and passed on to the users in order to reduce their charging costs. For the EFO, reduction of EV charging costs is also a business use case with ELVIS. For EVUs reduction of EV charging costs is also essential as the charging payments are a big part of their daily expenses. With the implementation of a scheduled charging (BUC-06: Use Smart Charging), the cost of charging sessions can be significantly reduced with lower prices or the provision other incentives.

Stakeholder: EVO, EFU, EFO

VI.3. BUC-03: Optimal Market Participation (for EVA and ES)

Market participation is one of the main and most interesting parts of ELVIS project. The available flexibility from the controllable CSs can be reformed in reserve offering to the existing balancing market as it is or extend the business plans of ELVIS when flexibility markets will be architected and executed by the system's operators. Optimal participation in the markets with the implementation of optimization algorithms that will automatically give optimal offers for all kinds of reserve products, or/and flexibility will be beneficial to ELVIS as business case but also to the market as a whole. The DSO will have more resources available for the network's stable operation, the TSO will have more resources available in the balancing market making it more competitive, and of course EVA will have financial benefits from the trading earnings as well as the CSP that will also get rewarded for the available flexibility.

Stakeholder: DSO, TSO, EVA, CSP

VI.4. BUC-04: Increase Potential Customer Base

Increasing the potential customer base is a major BUC for many of the involved commercial stakeholders. With the participation in ELVIS and the suggestions (for EV rental and CS allocation) from the ELVIS platform, CSP/CStO can potentially acquire new customers, which otherwise would have been out of reach. Due to better management of demand and optimized allocation of EVs, more customers can be served. ESs, Local Businesses can increase their pool of customers. A local business for example could offer incentives in the form of coupons via the ELVIS mobile app in order to attract customers. In addition, RES Stations will have new opportunities to come to Power Purchase Agreements with ES to secure part of their production for EV charging needs.

Stakeholder: CSP, CStO, ES

VI.5. BUC-05: Additional e-Mobility Services

This BUC can extend BUC-05. With the participation in the ELVIS solution, some stakeholders get the chance to offer additional services to third-parties. This may be beneficial in order to enhance marketing activities, e.g., a CSP (or CStO, depending on the business model) may advertise green (high share of renewables) or cost-efficient charging. For other stakeholders, participation in ELVIS may offer an extension or adjustment of their existing business models. For example, an ES may design a new energy delivery contract or additional pricing models based on the solution’s opportunities.

Stakeholder: CSP, CstO, ES

VI.6. BUC-06: Use Smart Charging

Smart charging is used to adapt charging time and charging level during charging sessions based on power system conditions throw wholesale market mechanisms. Smart charging application is dependent from different parameters like for e.g.: connection capacity, maximum charging rate, available battery capacity, and battery state-of-charge, customer preferences. EVUs can minimize charging cost by using smart charging technology from ELVIS in terms of providing a grid friendly service to DSO and/or TSO while simultaneously considering user priorities.

Stakeholder: CSP, EVO, EFU, DSO, TSO

VI.7. BUC-07: Secure Distribution Grid Stability

Network operators are obliged to ensure a certain power quality based on EN 50160. By using a distributed charging station infrastructure and an intelligent communication and control management system, grid-friendly services can be fostered for secure and reliable network operation. Load regulation allows controlling voltage changes at local level. Different EVs cause certain grid repercussions, due to different charging modes and inverters. For a stable grid operation, it is essential to understand the possible impact of repercussions to the grid in order to use this knowledge for a suitable grid expansion or appropriate control strategies.

Stakeholder: DSO

VI.8. BUC-08: Optimal Networks Congestion Management

A network-friendly smart charging minimizes the impact of charging on power quality. The DSO can buy the provided flexibility to defer network grid expansion to a certain extent. Due to the high simultaneous charging of regional near charging stations, congestion management might be necessary in the short term. In order for this case to be utilized, DSO and TSO should provide the necessary infrastructure for players in the flexibility market to be able to submit their offers. Therefore, a new BUC (BUC-03: Optimal Market Participation (for EVA and ES)) can be explored with optimal bidding strategies technologies utilization.

Stakeholder: DSO

VI.9. BUC-9: Forecast Energy Consumption

Another very interesting BUC for the ES is the short-term (24h-48h ahead) prediction of the energy consumption based on ELVIS data. Depending on the amount of ELVIS participants, the forecasts can become very accurate, which would help the ES in acquiring the necessary energy directly from the wholesale electricity market or bilaterally through power purchase agreements. This BUC could also be beneficially for CStOs when it comes to maintenance management and infrastructure development. Prediction of the energy consumption is also very helpful for the EVA that participates in ancillary services markets (i.e., balancing market at system level or flexibility local markets at distribution level) providing flexibility in return for revenues.

Stakeholder: ES, EVA, CStO

VI.10. BUC-10: Reduce EV Ownership Costs

For EVO and EFO, reduction of the overall costs of EV ownership is an important business use case. ELVIS aims at fostering a battery-friendly charging behavior and charging methods so the state-of-health and the expected life of the battery to not be harmed by the smart charging and the participation to the market. In case the battery of the EV is also owned by the EVO or EFO, this naturally will reduce the costs for batteries replacement and subsequently also the costs for EV ownership.

Stakeholder: EVO, EFO

VI.11. BUC-11: ES – EVA Coordination

Coordination when separate legal entities

Stakeholders: ES, EVA

VII. ELVIS KPIs

Key Performance Indicators (KPIs) are the critical (key) indicators of progress toward an intended result. The list of ELVIS KPIs can assist in creating an analytical basis for performance evaluation and optimal decision making, by focusing on crucial matters.

The main KPIs regarding ELVIS are highlighted in the following main categories:

- Charging Station Infrastructure
- Electric Vehicle Fleet
- EV Users
- Electricity Markets
- Performance Evaluation of Developed Tools
- Social and Environmental

VII.1. Charging Station Infrastructure

Performance indicators on the Charging Station infrastructure level can be used to evaluate the selected architectural approach and the platform utilization. The quantification of these indicators is based on data derived from both the OCPP and energy metering subsystems and corresponding to the managed CSs. Below, we present a non-exhaustive list of targeted KPIs.

VII.1.1. Number of Managed CSs

This metric is used to quantify the number of CSs that are connected to and managed by ELVIS. This parameter is expected to grow over time, as the ELVIS system is being gradually adopted by more CPOs, resulting in an increasing number of CSs being connected to the system.

VII.1.2. Number of Available Charging Points

This metric can be directly derived by the preceding one, by considering the number of charging points that are available per CS. It can be particularly useful for calculating the capacity of EVs that can be simultaneously connected to the ELVIS managed fleet of CSs. For example, one-plug CSs can charge only one EV whereas, the two-plug CSs can handle up to two simultaneous charging sessions.

VII.1.3. Number of Connected EVs over a Time Interval

This metric is used to quantify the number of connected EVs on CSs managed by ELVIS over a given time interval. In detail, this KPI can provide a realistic approach for determining the number of EVs being connected (charging or not) during a time period. Although CS utilization fluctuates during the 24-hour period, the isolation of charging sessions into batches based on time intervals can assist in accurately estimating the high and low utilization periods during the day. It must be noted that the number of connected EVs cannot exceed the total number of available charging points.

VII.1.4. Number of Simultaneous Charging Sessions

This metric is an extension of the previous metric, which focuses on the number of EVs that are simultaneously charging on an ELVIS managed CS.

VII.1.5. Number of Unique EVUs Serviced Over a Time Interval

This metric highlights the number of unique EVUs that have connected and charged their EV on any ELVIS managed CS, over a specific time window. In detail, this parameter is particularly useful for understanding the adoption of the ELVIS system from the perspective of the end users.

VII.1.6. Number of Charging Sessions Completed Over a Time Interval

This metric provides information about the number of charging sessions that have been completed on an ELVIS managed CS over a specified period. The metric aims at estimating the ELVIS platform utilization over time.

VII.1.7. Average Charging Session Duration Over a Time Interval

The average charging session duration can provide an estimation about the behavior of the serviced EVUs. From the CS fleet perspective, the proposed metric can provide information about the charging utilization of the overall CS fleet. However, given this information about the charging periods where the utilization is on peak load can be considered critical for the optimization of the smart grid. From an individual perspective this metric is essential for extracting meaningful information about charging patterns of specific EVUs. In addition, it is possible to estimate the inactive duration time, both on the overall CS fleet level and also on the individual EVU level.

VII.1.8. Average Power Demand for the Whole Managed CS Fleet Over a Time Interval

This metric is used to highlight the power demand of the CS fleet that is requested over a specific time interval. Indicatively, this metric can be of high importance, because the average power demand of ELVIS managed CSs across a given time interval can be particularly useful for supporting the forecasting tools of ELVIS.

VII.2. Electric Vehicle Fleet

This category includes KPIs related with information that can be exposed by the connected EVs based on data exchanges that are supported by the ISO-15118 standard. ISO-15118 allows the EV and CS to dynamically exchange information based on which a proper charging schedule can be (re-)negotiated. During the charging session, the CS and the EV continuously exchange information. The considered KPIs are required for guaranteeing an optimum charging schedule for each EV by using the information available about the state of the electrical grid, the energy demand of each EV, and the mobility needs of each driver. It is important to note that the following KPIs might not be calculated for CSs or EVs that do not support the ISO-15118 standard. Considering that the standard adoption is increasing, a list of non-exhaustive ISO-15118 based KPIs was included.

VII.2.1. Mean Starting State of Charge (SoC)

The mean starting percentage value of the battery can be provided via the ISO-15118. This derives from averaging every charging session from on an individual level. This value can be used to categorize the user’s behavior and patterns. Moreover, measurements for the battery's lifetime can be estimated and used from analysis.

VII.2.2. Estimated Charging Time Duration

The charging duration is calculated by subtracting the departure time value by the time of arrival of the EV. This in-depth value can provide information about individual EV users' schedules which may vary and enables ELVIS to create personalized behavioral models. Along with this information, assumptions for the average charging duration and possible disconnections prior to the fully charged sessions can be gathered for stochastic purposes. Recent research work (Wang, et al., 2017) has also proven that the charging duration is strongly correlated with the energy consumed in the session.

VII.2.3. Estimated Achievable Trip Range

Estimations for the possible trip range on an individual level can also be made based on the SoC. In order to accurately estimate the possible trip range parameters from the user's perspective are mandatory, such as EV's model, battery capacity, battery's state of health.

VII.2.4. Battery Health

The battery's lifetime is significantly affected by the typical characteristics of the charging sessions that have been completed. The battery health parameter exchange is supported by a compatible ISO-15118 CS and EV (Tridens Technology, 2020). Charging recommendations can also be implemented, in order to prolong the battery's lifetime and state of health.

VII.2.5. Potential Energy Demand Over a Time Interval

This metric can be calculated, over the entire fleet of charging EVs, as an aggregation of the amount of energy that will be requested over the specified time interval, in order for all the EVs to reach the target SoC. This metric can be particularly useful for supporting the forecasting tools of ELVIS.

VII.3. EV Users

This category includes KPIs that are directly related with the end EV users and can be extracted by both from user preferences logged through the smartphone application or analyzing data related with historical charging sessions per user. Below we present a non-exhaustive list of targeted KPIs.

VII.3.1. Preferred CS Distribution

In most cases, EVUs tend to charge on a limited set of CSs, whose location is preferred due to proximity to their home or work location. By monitoring the list of preferred CSs per EVU, we can calculate the distribution of preferred CSs per EVU. This metric can be particularly useful for supporting the forecasting tools of ELVIS.

VII.3.2. Timing Profiles

This category includes metrics related with the timing preferences for charging the EV, corresponding to time windows per day that are preferred by each EVU. Combining the user's behavior and preferences results in accurate estimations and detailed user profiling. This metric can be combined with the geographic locations of the preferred CS to result in more complex user profiling.

VII.3.3. Mean Duration of in-App Activity Over a Time Interval

In app activity is essential for providing realistic information about user adoption rate and usage time. It must be noted that this KPI can be either targeted for individuals or on a massive scale for analytical purposes, however this metric is directly dependent on time interval calculations (hour, day, week, month, etc.). Moreover, categorization for the EVUs can be made on whether the app is utilized at its full potential or modifications are needed to increase adoption rate. Although in-app activity is a metric specifically targeted to end users, possible limitations can be gathered for future improvements either to the business model or to the app.

VII.4. Electricity Markets

This category includes KPIs that are directly related to the impact of smart charging on electricity markets indices.

VII.4.1. Balancing Market Competitiveness

The more resources available for providing balancing service, the more competitive the balancing market will be. This metric quantifies the increase in available balancing potential (in MWh available for balancing energy up and down), at TSO level, from the utilization of smart charging, compared to the case of conventional charging

VII.4.2. Balancing Market Price Reduction

Increasing competitiveness of the balancing market reduces the opportunities for balancing market pricing speculation on behalf of the BSPs. BSPs scope is to increase their chance to be cleared in the balancing market, maximizing their profits. Under strong competition, BSPs must offer at price more and more close to the marginal cost of proving the balancing service. This metric identifies the balancing market price reduction as a results of smart charging utilization.

VII.4.3. Costs-savings from Smart Charging

This metric identifies how the charging cost is reduced under smart charging scenarios compared to the case of conventional charging.

VII.4.4. Revenue from Wholesale Market Participation

This metric identifies how the introduction of innovative bidding strategies can maximize or introduce new revenue streams for EVAs and/or other market participants.

VII.5. Performance Evaluation of Developed Tools

VII.5.1. Accuracy of Load Forecast Calculated 24 hours in Advance

The metric provides information about the accuracy of the forecasted value, calculated 24 hours in advance, comparing with the actual value of the load of the EVs. This information is critical because many decisions regarding smart charging are bound to the forecasted load and maximizing the accuracy of the prediction affects both the EVAs revenues as well the competitiveness.

VII.5.2. Accuracy of Load Forecast Calculated 1 hour in Advance

This metric is identical with the previous, with the only difference that the comparison is between the forecasted value calculated 1 hour in advance and the actual value.

VII.6. Social and Environmental Impact

VII.6.1. CO2 Reduction due to RES Exploitation

Smart charging will increase the exploitation of renewable energy and as a result decrease the production of CO^2. This metric calculates the amount of CO^2 that is avoided per Charging session due to the smart energy solution.

VII.6.2. Share of Renewable Energy Used for Charging

Smart charging cooperated to BaU charging offer better exploitation of RES. As a result, this metric will estimate the amount of RES energy used for the charging session, compared to BaU.

VII.6.3. Distance Traveled for EV Charging

The distance that an EV must travel in order to reach an EV charger, could have a significant share over the total distance traveled between charging sessions. This metric identifies this distance and calculates batteries SoC used for this purpose.

References

A, P., S, S. O., & B, R. (2015, May). Applying High Performance Computing to Transmission-Constrained Stochastic Unit Commitment for Renewable Penetration. *IEEE Transactions on Power Systems*(30), pp. 1690-1701.

Agile Software Development Methods: Review and Analysis. (n.d.). Retrieved from http://b.link/stream24

Alipour, M., Mohammadi-Ivatloo, B., Moradi-Dalvand, M., & Zare, K. (2017). Stochastic scheduling of aggregators of plug-in electric vehicles for participation in energy and ancillary service markets. *Energy*, pp. 1168–1179.

Amini, M. H., Karfarian, A., & Karabasoglou, O. (2016, November). ARIMA-based decoupled time series forecasting of electric vehicle charging demand for stochastic power system operation. *lectric Power System Research*, pp. 378-290.

ASEM ISLAND MOBILITY SERVICES. (2021). Retrieved from https://asem-mobility.gr/

Atlam, H., Alenezi, A., Alassafi, M., & Wills, G. (2018). Blockchain with Internet of Things: benefits, challenges, and future directions. *Int. J. Intell. Syst. Appl.*, pp. 40–48.

Bessa, R. J., & Matos, M. A. (2010). The role of an aggregator agent for EV in the electricity market. *7th Mediterranean Conference and Exhibition on Power Generation, Transmission, Distribution and Energy Conversion (MedPower 2010)*.

Biskas, P., Marneris, I., Chatzigiannis, D., Roumkos, C., Bakirtzis, A., & Papalexopoulos, A. (323–341). High-level design for the compliance of the Greek wholesale electricity market with the Target Model provisions in Europe. *Electric Power Systems Research*, pp. 323–341.

Burger, C., Kuhlmann, A., & Richard, P. (2016). Blockchain in the energy transition. *A survey among decision-makers in the German energy industry*.

Carge App. (2021). Retrieved from https://carge.co/

Castro, M., & Liskov, B. (1999). Practical byzantine fault tolerance. *Proc. 3rd USENIX Symp. on Operating System Design and Implementation*, pp. 173–186.

Deloitte. (2016). *Blockchain: Enigma. Paradox. Opportunity*. Retrieved from https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/Innovation/deloitte-uk-blockchain-full-report.pdf

Diffie, W., & Hellman, M. (1976). New directions in cryptography. *IEEE Trans. Inf. Theory*, pp. 644-654.

DIRECTIVE 2009/73/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 July 2009 concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC. (2009, July 13). Retrieved from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:211:0094:0136:en:PDF

Docile CP Simulato. (2021). Retrieved from github.com/NewMotion/docile-charge-point

Dwork, C., & Naor, M. (1992). Pricing via processing or combatting junk mail. *Annual International Cryptology Conference*, pp. 139–147.

EASAC. (2009, 5). *Transforming Europe's Electricity Transforming Europe's Electricity for a Reliable, Renewable and Secure Power System.* Retrieved from https://easac.eu/fileadmin/PDF_s/reports_statements/Transforming.pdf

Electric vehicle stock in the EV30@30 scenario, 2018-2030, IEA, Paris. (2020). (IEA) Retrieved from https://www.iea.org/data-and-statistics/charts/electric-vehicle-stock-in-the-ev3030-scenario-2018-2030

Electric vehicles, Setting a course for 2030. (2020, July 28). (Deloitte Touche Tohmatsu Limited) Retrieved from https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html

Electrific, a European Union's Horizon 2020 Project. (2020). Retrieved from European Union's Horizon 2020

Energy, G. M. (2020). *Transition to Low Emission Mobility: Promotion Measures and Operation.* Retrieved from http://www.opengov.gr/minenv/wp-content/uploads/downloads/2020/06/sxedio_nomou.pdf

European Alternative Fuels Observatory (EAFO, 2020). (n.d.). Retrieved from https://www.eafo.eu/countries/greece/1735/summary/compare

European Commission. (2018). *Guidance on Energy Transmission Infrastructure and EU nature legislation.* Retrieved from https://ec.europa.eu/environment/nature/natura2000/management/docs/Energy%20guidance%20and%20EU%20Nature%20legislation.pdf

EVRoaming Foundation. (n.d.). Retrieved from https://evroaming.org/

EV-Volumes.com. (2021, August). Retrieved from https://www.ev-volumes.com/

Global EV Outlook 2019. (2019). (IEA) Retrieved from https://www.iea.org/reports/global-ev-outlook-2019

Helmus, J. R., Lees, M. H., & Hoed, R. v. (2020,, June). A data driven typology of electric vehicle user types and charging sessions. *Transportation Research Part C: Emerging Technologies*.

Hoogvliet, T. W., Litjens, G. B., & Van Sark, W. G. (2017). Provision of regulating and reserve power by electric vehicle owners in the Dutch market. *Applied Energy, 190*, pp. 1008–1019.

Hou, J., Wang, C., & Luo, S. (2020). How to improve the competitiveness of distributed energy resources in China with blockchain technology . *Technol Forecast Soc Change*, p. 151:119744.

How battery storage can help charge the electric-vehicle market. (n.d.). pp. https://www.mckinsey.com/business-functions/sustainability/our-insights/how-battery-storage-can-help-charge-the-electric-vehicle-market.

Hubject. (n.d.). Retrieved from https://www.hubject.com/

Hubject. (2019, 5 15). *OICP goes Open Source*. Retrieved from https://www.hubject.com/blog-posts/oicp-goes-open-source

Huh, J.-H., & Kim, S.-K. (2019). The Blockchain Consensus Algorithm for Viable Management of New and Renewable Energies. *Sustainability* , p. 3184.

Independent Power Transmission Operator S.A. (2021). Retrieved from https://www.admie.gr/en

IPTO. (2019). *Balancing Market Rulebook*. Retrieved from https://www.admie.gr/en/market/regulatory-framework/balancing-market-rule-book

IRENA. (2019, May). *Innovation outlook – Smart charging for electric vehicles*. Retrieved from https://www.irena.org/publications/2019/May/Innovation-Outlook-Smart-Charging

Li, Y., Huang, Y., & Zhang, M. (2018, May). Short-Term Load Forecasting for Electric Vehicle Charging Station Based on Niche Immunity Lion Algorithm and Convolutional Neural Network. *Energies*.

New Zealand's Transport Agency. (n.d.). *Charging point connectors and socket outlets.* Retrieved from https://www.nzta.govt.nz/planning-and-investment/planning/transport-planning/planning-for-electric-vehicles/national-guidance-for-public-electric-vehicle-charging-infrastructure/charging-point-connectors-and-socket-outlets/

OCPI, F. E. (2020, 12 06). *Open Charge Point Interface*. Retrieved from https://evroaming.org/app/uploads/2020/06/OCPI-2.2-d2.pdf

OCPP.Core. (2021). Retrieved from https://github.com/dallmann-consulting/OCPP.Core

OCPP-1.6-Chargebox-Simulator. (n.d.). Retrieved from https://github.com/victormunoz/OCPP-1.6-Chargebox-Simulator

Open Charge Alliance. (n.d.). Retrieved from https://www.openchargealliance.org/

Pilkington, M. (2016). Blockchain Technology: Principles and Applications. *Research Handbook on Digital Transformations*.

PPC, P. P. (2010). *Transmission.* Retrieved from https://www.dei.gr/Images/DEI%20Transmission%20eng.pdf

RAE. (2018). *Κανονισμός λειτουργίας της Αγοράς Επόμενης Ημέρας και της Ενδοημερήσιας Αγοράς».* Retrieved from https://rae.gr/wp-content/uploads/2020/12/2018.pdf

Regulatory environment and incentives for using electric vehicles and developing a charging infrastructure. (n.d.). (German Federal Ministry for Economic Affairs and Energy) Retrieved from https://www.bmwi.de/Redaktion/EN/Artikel/Industry/regulatory-environment-and-incentives-for-using-electric-vehicles.html

Scriptable OCPP Chargepoint Simulator. (2021). Retrieved from https://github.com/oglimmer/scriptable-ocpp-chargepoint-simulator

Steve OCPP management system implementation. (n.d.). Retrieved from https://github.com/RWTH-i5-IDSG/steve

Stryja, C., Fromm, H., Ried, S., Jochem, P., & Fichtner, W. (2015, January 07). On the Necessity and Nature of E-Mobility Services – Towards a Service Description Framework. *Lecture Notes in Business Information Processing*(201).

Time for Norway to tax luxury electric cars, IMF economists say. (2021, June 10). (Reuters) Retrieved from https://www.reuters.com/business/autos-transportation/time-norway-tax-luxury-electric-cars-imf-economists-say-2021-06-10/

USEF. (2021). *USEF: THE FRAMEWORK EXPLAINED.* Retrieved from https://www.usef.energy/our-final-release-the-framework-explained-2021/

Using ISO 15118 Plug & Charge with OCPP 1.6. (2020, 09 16). Retrieved from https://www.openchargealliance.org/uploads/files/ocpp_1_6_ISO_15118_v10.pdf

Vagropoulos, S. I., & Bakirtzi, A. (2013, November). Optimal bidding strategy for electric vehicle aggregators in electricity markets,. *EEE Transactions on Power Systems*, pp. 4031-4041.

Vagropoulos, S. I., Kardakos, E. G., Simoglou, C. K., Bakirtzis, A. G., & Catalão, J. P. (2016, May). ANN-based scenario generation methodology for stochastic variables of electric power systems. *Electric Power Systems Research*, pp. 9-18.

Vagropoulos, S. I., Kyriazidis, D. K., & Bakirtzis, A. G. (2016, March). Real-time charging management framework for electric vehicle aggregators in a market environment. *EEE Transactions on Smart Grid*, pp. 948-957.

Wang, B., Wang, Y., Nazaripouya, H., Qiu, C., Chu, C.-C., & Gadh, R. (2017, FEBRUARY). Predictive Scheduling Framework for Electric Vehicles With Uncertainties of User Behaviors. *IEEE INTERNET OF THINGS JOURNAL*.

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