TwinEV module

D7.6

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Deliverable

PROJECT ACRONYM	GRANT AGREEMENT #	PROJECT TITLE
TWINERGY	**957736**	**Intelligent interconnection of prosumers in positive energy communities with twins of things for digital energy markets**

D7.6
TwinEV Module

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Statement of Originality

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

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Executive summary

This present document is D7.6 "TwinEV Module" of the TwinERGY project, funded by the European Commission's Innovation and Networks Executive Agency (CINEA) under its Horizon 2020 Research and Innovation Programme (H2020). This deliverable presents the design and results related to the development of the TwinEV module. The deliverable is focused on the results of the work carried out under Task 7.6 "TwinEV Module" that is intended to create a module that accounts for high-value services to EV users, such as minimum charging prices, maximum green electricity supply and different kinds of grid services. This deliverable is developed under WP7, whose aim is to deliver several modules that can work on a complimentary basis. The purpose of the delivery within the context of TwinERGY is threefold:

- The development of the architecture of the TwinEV module and its relation to the Use Cases (UC) development which was defined and provided in WP2 "Stakeholder Requirements, Obstacles to innovation and Business Models" and WP4: "Methodological framework and Architecture Design".
- The development of the applications that will shape the TwinEV module to achieve the functionalities to allow the provision of **high-value services to EV users**. These applications must fulfil the specifications set by the TwinERGY pilots so that advanced benefits could be offered to EV users but also to the energy distribution systems.
- The presentation of the developed applications in a user-friendly interface.

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1. Introduction

1.1. Scope of the document

The deliverable is focused on the results of the work carried out under Task 7.6 "TwinEV Module", whose aim is to design and develop a module that provides high-value services to EV users. This module is based on a Smart Charging Tool whose aim is to provide a more user central and cooperative approach to the EV charging processes.

Among the services that the tool is providing, it can be highlighted the search of minimum charging process, the maximum green electricity supply, supporting drivers to find the most suitable station (based on dynamic pricing, route cost to the station, amount of the vehicle's battery or energy that can be provided), as well as handling the booking and parking processes. These functionalities will be developed under a user-centric and cooperative approach.

This deliverable is developed under WP7 that targets the development of a set of modules that work jointly in order to provide the consumers with a wide range of services based on the data analysis. For that purpose, these modules will be based on the specifications drawn by the different modules (from WP2 and WP4). The functionalities for this module will be based on interoperability principles, from which basis for the TwinERGY environment were described in Task 7.1 "Modules' specification and system interoperability", which deliverables' due date was June 2021.

The purpose of this deliverable within the context of TwinERGY is threefold:

- The development of the architecture of the TwinEV module and its relation to the Use Cases (UC) development which was defined and provided in WP2 "Stakeholder Requirements, Obstacles to innovation and Business Models" and WP4: "Methodological framework and Architecture Design".
- The development of the applications that would shape the TwinEV module to achieve the functionalities to allow the provision of **high-value services to EV users**. These applications must fulfil the specifications set by the TwinERGY pilots so that advanced benefits could be offered to EV users but also to the energy distribution systems.
- The presentation of the developed applications in a user-friendly interface.

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1.2. Structure of the deliverable

The document is structured as follows. Section 1. Introduction is the introductory section of the deliverable which presents the purpose, the structure, and the abbreviation list. Section 2.Objectives will deeply analyse the objectives that Deliverable 7.6 "TwinEV module" intends to address. An introduction to the Electric Mobility will be performed in Section 3.Electric Mobility as a Service Module, so that the basis under which the TwinEV module are based, could be large explained in the beforementioned section. Section 4.Architecture will provide an overview of the TwinEV concept, and its relation to the developed work in WP2 and WP4.

Additionally, it will present the different submodules and services that composed the TwinEV module (ECOVE, HUB and SMAC). Section 5. Data Interchange will provide a review of the data that is shared with the rest of the TwinERGY ecosystem, based on the specification set for the TwinEV module.

This deliverable will particularly focus on the data models, sources and protocols that will be used. Section 6. Applications would take a look of the technology used to create the applications, but also the technology used to create the user-friendly interfaces that the TwinEV is going to present. Section 7. Deployment and Testing will shortly introduce the deployment and testing plan, which will be further elaborated in Section 8. TwinEV in Pilots will give a brief overview on the pilot demonstration sites in which the TwinEV is being tested (Germany and Greece). Finally, Section 9. Conclusions will provide an overall information stating the most relevant information presented in this deliverable.

1.3. Abbreviation list

Table 1: Abbreviation List

Acronym	Full Name
CP	Charging point or Charge point
CPO	Charging Point Operator
DSO	Distributed System Operator

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eMIP	eMobility Interoperation Protocol
EMSP	eMobility Service Provider
EU	European Union
EV	Electric Vehicle
EVSE	Electric Vehicle Charging Station
H2020	Horizon 2020
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
LEM	Local Energy Markets
POI	Point of Interest
RES	Renewable Energy Sources
REST	REpresentational State Transfer
SCSP	Service Provider Actor
SMAC	Smart Charging Tool
SoC	State of Charge
SoC	State of Charge

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TEM	Transactive Energy Module
TRL	Technology Readiness Level
UC	Use Cases
V2G	Vehicle-to-Grid
VM	Virtual Machines
WP	Work Package

2.Objectives

WP7 "Development of TwinERGY system Modules" is reflected on the Innovation Lab Phase within the TwinERGY project. Within this phase, partners are expected to deliver their prototypes for the modules developed so that they can be tested and scaled. For this purpose, a prototype phase has been employed as a first step. The sets of data and technological tools proposed in previous phases (Design Thinking Phase from WP4: Methodological Framework and Architecture Design and WP6: Development of Digital Twin Platform & System Dynamics) will allow the exploration ideas that would be used to validate in a cost-effective manner these objectives.

Thereafter, a deploying phase is being proposed. Through this step, TwinERGY will prove the effectiveness of the technical and non-technical solutions from where the new created solutions can be deployed. WP8: TwinERGY system integration will make feasible this verification.

Finally, the Innovation Lab phase concludes with the validation, in which the residents test the final solution. It is worth mentioning that the Innovation Lab phase (WP7 & WP8) is going to receive inputs from the Ecosystem Analysis Phase, from which the foundations of the TwinERGY project will be settled down. The last step would have users test the developed prototype solution to validate it on the Scale Phase (WP9: Pilots). Throughout this phase, the different pilots based on different countries will allow the study of a solution replicability though the different activities performed in the demonstration sites thanks to the Design and Innovation Lab phases. Figure 1 presents schematically the different phases and its relation to the WP development.
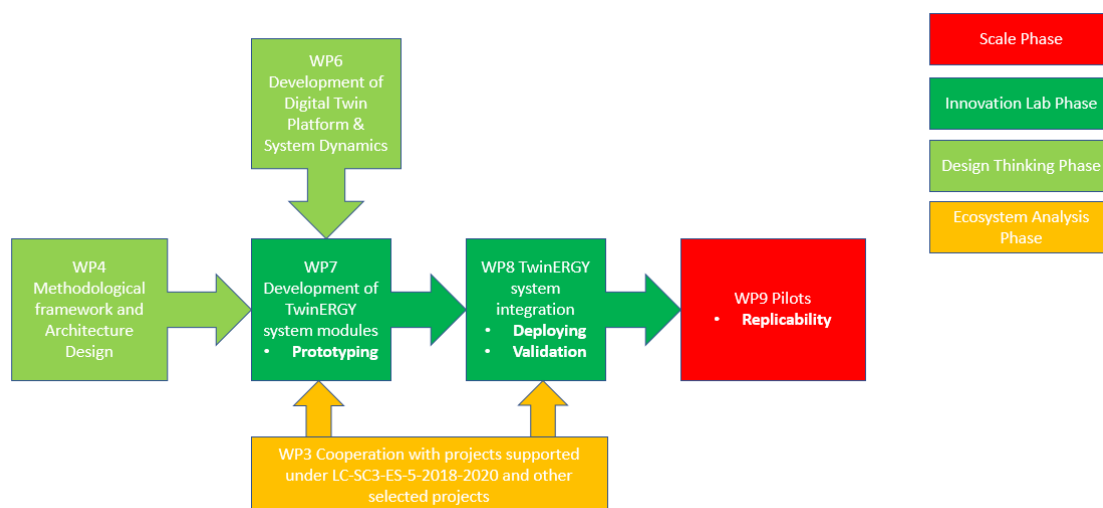
Figure 1: Interconnection between different WP in TwinERGY

EV users will be provided with a user-friendly interface with which they will be able to address issues of payment, security, quality, and configuration of their EV charging profile. Regarding public infrastructure, the most suitable charging point (CP) will be indicated to EV user, based on some principles such as prices, route cost to station, the energy stock and the waiting-charging times. The platform will be also able to process booking and parking processes for the public EV chargers.

Smart electric vehicles charging, or dynamic load management is referred to a system where a charger communicates with the car and the Charging Point Operator (CPO), and exchange information to optimize the process of charging. Smart charging also allows the monitorization, restriction and remotely management of the energy delivered in order to optimize the energy costs. Additionally, the amount of power supplied can vary depending on several factors, such as the number of EV charging, the maximum power capacity, or the energy tariff that the charging post is subscribed to. A series of benefits can be extracted from the smart charging process, such as the adaptation to meet the particular customer's needs while reducing its operational costs. The overall goal is to calculate the optimum charging profile, that is to say, the amount of power that should be delivered to a given charging session at a given moment, based on the several restrictions and conditions presented at a given time. At TwinERGY, the TwinEV module will address these challenges through the SMAC algorithm, which will provide the charging profile dynamically calculated. This algorithm is described in section 4.6. Smart Charging Tool (SMAC).

3.Electric Mobility as a Service Module

Nowadays, the European Union (EU) is combating climate change through interventions in the transportation sector. Over the last 25 years, European rules have promoted the reduction of pollutants emissions through the carefully guidance of vehicles' manufacturers. Nevertheless, today's huge effort is required in the reduction of CO_2 emissions through the electrification of transportation. The main regulatory framework related to e-mobility is as follows:

- Directive on Alternative Fuels Infrastructure (2014/94/EU)
- CO_2 Emissions for Cars and Vans Performance Standards (EU 2019/631)
- Trans-European Network for Transport (TEN-T) Regulation review
- Clean Vehicles Directive (2019/1161 EU)
- Sustainable and Smart Mobility Strategy

Performing a comparison between an Electric Vehicle (EV) and an Internal Combustion Engine (ICE) vehicle, it can be stated that EV perform at a higher efficiency with less mechanical reliability and has no direct associated CO_2 emission. Furthermore, the EV stores energy through electrochemical batteries (less energy density than liquid fuels). However, EV batteries could be charged at least 5 times slower than liquid fuel refuelling [1].

E-mobility is a key element in the future energy system. This practice generates effects both as an additional load and as a flexibility resource for market actors and system operators. The capabilities of EVs are many and varied since they can provide valuable system flexibility services and management of congestion in transmission grids. For this purpose, the development of a suitable charging management system is required to address different stakeholders' needs in the electro-mobility value chain. According to the literature [1], leaving the charging process uncontrolled could hinder some of present challenges in the power system, such as peak power demand at certain times. The benefits of managing the charging process regarding the power profile will open new opportunities to the system. It should also be mentioned that a smart EV charging approach can support the integration of RES resulting in a reshape of the power demand curve (reducing the system costs and CO_2 associated emissions).

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Some other underlying aspects associated to the correct spread of smart charging are the standardization, as well as the dynamic pricing definition, market rules. These facts require the cooperation among many different actors from diverse sectors such as: vehicle, batteries, electronic industries, ICT, mobility service providers, transport authorities, electricity market aggregators, consumers, and power grid operators. ENTSO-E [1] suggest some topics which could facilitate the implementation of smart-charging solutions.

- Coordinate charging infrastructure and electric grid scenario.
- Manage the charging process (considering V2G charging approach if possible) to smooth peaks in the load curve.
- Deploy electromobility enablers in public and private charging infrastructure, with metering and communication capabilities.
- Enable a new ecosystem centred around the consumer needs, by enhancing defined roles, responsibilities to exploit the potential of EV charging as a flexible resource.
- Update market rules and regulatory framework.

Within the context of the TwinERGY project, the TwinEV module aims to adjust its goal of consumer engagement in Demand Response and local optimization in the field of the EV and its dual role as a demand and storage asset. The objective is to analyse the impact that the charging scenarios could imply on the community in terms of grid congestion and the welfare of individual members. To achieve this goal, the TwinEV module will compile EV user's preferences and requirements to adjust the services and features to be provided.

The objective of TwinEV is to provide the required and optimized EV users' State of Charge at proper times, considering minimum charging prices and the delivery of maximum green electricity supply to EV, based on local energy demand rationalisation. In this sense, Electrical vehicles offer a huge flexibility potential. EV has the potential of shifting the demand, and it can be further improved if V2G functionalities are applied, since they can give back energy to the distribution grid when necessary. It is worthwhile to remark that this last functionality could have a positive impact to the grid. In case of congestion, DSO would be able to send signal to EV to limit their congestion constraints on the grid. Furthermore, additional ancillary services can be provided by electric vehicle's battery in terms of voltage control, peak shaving, and energy buffering for RES intermittency.

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For TwinEV module to perform the optimized State of Charge (SoC) and to be centralized at the consumer engagement, there are several constraints and parameter that must be considered. Physical limits such as battery capacity, current State of Charge of the Vehicle, maximal and minimal power generation, localization of Charging Points and their respective power on charge process play an important role in the determination of a proper charging profile. These inputs would be compiled through the preferences of each EV users, the technical requirements of the grid and the different assets, as well as the calculation of the Demand Response campaigns resulting in flexibility assessment [2].

TwinEV offers a user-friendly for drivers, where users can manage payments, security, quality, and configuration of other topics related to e-mobility. These topics include making a recommendation about the most suitable charging point, based on some principles such as prices, route cost to station, the energy stock and the waiting-charging times. The platform is also able to process booking and parking processes for these regarded public EV chargers.

Furthermore, this would be combined to produce the calculation of the optimal State of Charge (SoC) for the user, in terms of minimization of the costs and maximization of the green electricity. This last part is required to be replicated at the private (domestic) EV chargers as well.

TwinEV is a module that it is going to be developed by ETRA, aiming in having a user-centric and cooperative approach within the context of the TwinERGY project. It is intended to achieve a Technology Readiness Level (TRL) of 8 at the end of the project.

4.Architecture

4.1. Introduction

The different modules are going to be integrated with the rest of the components in the TwinERGY solution. The different 9 modules deployed, will extract information not only from data collection devices (raw data), but they will also collect data from the Digital Twin Platform (though the iSCAN Platform), but also some derivative data from other modules through the TwinERGY Interoperable Platform (Based on NATS 2.0 Technology). This relation has been further explained in Deliverable 7.1-"Modules' Interoperability". Figure 2 gives an overview of how the different tools are being interconnected.
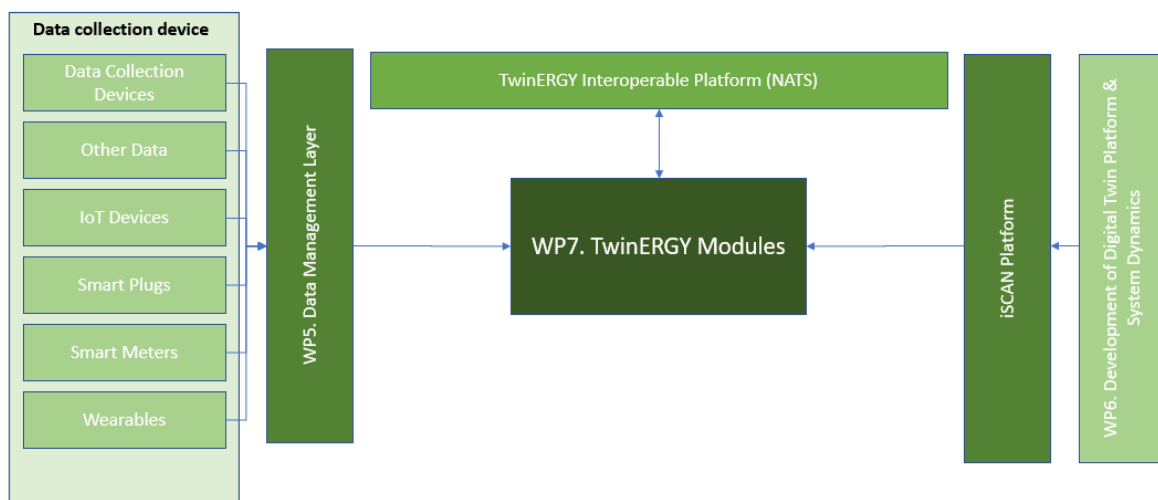
Figure 2: TwinERGY Interoperable Architecture

As explained in Chapter 3, TwinEV module is going to be designed to calculate the optimal State of Charge of an EV in terms of cost minimization and maximization of green electricity to supply. This optimization will consider the huge potential in terms of flexibility that EV can provide to report benefits to the grid management, grid congestion management, ancillary services, peak shaving and energy buffering to gather the RES intermittency. In addition to this, the EV will be considered to act as a battery (V2G capacities). All these functionalities will be addressed to the EV user through the distribution of a user-friendly interface which it is going to be fully depicted at this task. Through it, the EV user can perform an optimized charging process, based on the principles of security and quality of energy performance.

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The module will allow to EV driver the selection of a suitable public charging station through which they can proceed with the charging process. The selection of the charging point can be specified based on factors such as dynamic pricing, route cost to the station, arrival times and amount of battery. In addition to this, the module will allow EV users to handle the booking of the charging point as well as proceed with the payment of the charging process. The result of this charging process is supposed to have a direct impact on the grid management (Voltage and Congestion control), as well as the implementation of RES into the grid. Furthermore, V2G capabilities can affect the development of grid processes

On the other hand, EV in the private field can be used as a distributed storage asset that with the integration to Local flexibility Markets and Demand Response Campaigns within the context of TwinERGY project. In this case, TwinEV can provide an assessment of the Smart Charging profile for EV, taking into account Demand Response campaigns from the domestic field.

In the context of the project, TwinEV covers a range of features such as:

- Electric Mobility as a Service
- Smart Charging of EV
- Vehicle-to-grid
- Voltage Control and Grid Congestions by DSO
- Booking of shared electric vehicles.

Moreover, TwinEV helps to actuate over other goals in the project such as:

- Demand Response Campaigns
- Participation in Energy Markets
- Participation in Local Flexibility markets
- Integration of RES and surpluses
- Reduction of CO_2 emissions

The actors that could contribute to the smooth operation of the module are listed below:

- EV owners
- End-consumers (MV/LV) / Prosumers. In case of private charge points, the EV owner and end-consumer will be the same figure.
- Charging Point Operators
- Energy suppliers
- Aggregators
- Retailers

- Grid operators

4.2 Detailed functionalities

The main purpose of this section is to define the TwinEV module functionalities within the TwinERGY solution. These functionalities, as commented before, are based on the different objectives of the TwinERGY Modules. The scenario depicted by the TwinEV is:

- Configuration of data related to electric vehicles and private charge points
- Find the most suitable charging point, based on a ranking for the most suitable station.
- Reserve a charge pot in a public or semi-public charging station during a while, in order to proceed with the charge.
- Handling of the charging session process
- Smart charging
- Introduce limitations to CPs by grid operators, with the aim of solving problems in the grid.
- Use of vehicle-to-grid feature

Table 2: TwinEV requirements

Input	Description	Origin
Demand forecast	Forecast of demand over the next 24 hours	Module
Production forecast	Forecast of production over the next 24 hours	Module
Supply point max. power	Maximum power to be delivered simultaneously, considering, non-controllable demand, production and EVSE-related demand	Module
Supply point min. power	Minimum power to be received simultaneously, for V2G operations	Module

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Energy price	Curve of energy price for cost optimization	Module
EV battery capacity	Capacity of the EV that is charging	Module
EV SoC	Battery SoC of the EV that is charging	Module
Nominal power of connectors	Max. power the connector is able to deliver	Charging Point Configuration
Nominal discharge power of connectors	Max. power the connector is able to receive, for V2G operations	Charging Point Configuration
Target slots	Time when EV is required to be charged	Module
Target SoCs	Minimum SoC required by the EV at the target slot	Module
Flex. Order	Support operations to the grid consisting of modifications on the supply point power flow limit (either upper, allowing greater demand, or lower, imposing demand limitations).	Module
Opportunity cost	Additional cost considered to disincentive long-lasting charging sessions	Module

Based on the inputs presented at Table 2, the algorithm will be able to optimize the charging profile, in terms of cost minimization and RES integration. The origin of these inputs can be either from the pilot's asset or derive from other modules. The last one is going be explained in the forthcoming section.

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4.2.1. Interaction with other modules

TwinEV module is expected to interact with other modules and its calculations to obtain valuable data sets for its own interest. The main iterations with some of the modules that have been of interest to the functionalities of TwinEV are described in the following sections.

4.2.1.1 Consumer and Neighbourhood demand flexibility profiling modules

These two modules are being developed by IES. Based on the TwinEV functionalities aforementioned, the module requires a set of information that would be valuable for the development of the module. TwinEV requires the Forecast Energy consumption both at a domestic and a Neighbourhood level. These predictions will allow to determine the expected demand profile within a period. This is a valuable input that will contribute to the calculation of the algorithm. Furthermore, the optimization algorithm is required to have as an input the production forecast within the following 24 hours. Consumer and Neighbourhood demand flexibility profiling modules have identified some functionalities that can be run with the aid of calibrated models to the scoop of the domestic field that can provide the predictability of the forecasting of energy at a given time. In addition to this, the Neighbourhood demand flexibility profiling can predict the renewable generation for a given period based on the available capacity and the weather forecast.

4.2.1.2. DER management module

This module is being developed by TH-OWL. Based on TwinEV requirements, this module requires the maximum and minimum power to be supplied considering, non-controllable demand, production, and EVSE-related demand. DER management module is set to provide grid status functionalities such as the expected load and generation in the grid, as well as the grid status calculation in real time. This valuable information from the grid status is being used in TwinEV module so as to provide the optimal charging profile to EV users.

4.2.1.3. Transactive Energy module

This module is being developed by WEC. This module is a trading decentralised platform what serves novel block-chain enabled transactive market. Since the TwinEV is going to

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allow the charging of EV in public infrastructures, TwinEV is going to make use of the TE module since a financial transaction may be required. In addition to this, TwinEV module performs an optimization for the charging curve in which the price of energy is required. TE module is expected to provide these prices to TwinEV module. Furthermore, VE consumes energy from the grid, so V2G functionalities are expected to be proven within the context of the project. This energy consumption could greatly benefit from the Transactive Energy module. For that purpose, it is expected also an energy transfer from the EV to the grid. This module aims to support this process.

4.3. General Overview

TwinEV is a module created not from scratch, but mainly based on the architecture defined for H2020 European project MEISTER [3]. Only some characteristics implemented in MEISTER have been replaced with the aim of incorporating the communication with other modules developed within the WP7. In a summary, MEISTER is organised in a three layers architecture [4]. These layers are depicted in Figure 3 and are the following ones:

- **Applications**: Set of tools offering an interface for humans and specialized in a particular set of use case scenarios and/or business model in MEISTER project.
- **Services**: each of the tools conforming the software backend, designed and developed to offer a specialized interface to the applications and other services. These tools run continuously in the hosting platform, being ready to receive requests.
- **Adaptors**: a set of micro-services, each one specialized in the interaction of the services and/or urban infrastructure equipment offered by third-party entities or external systems. Adaptors deal with the specificities of the 3rd party services, infrastructures and data sources and allow services offering their functionality in a transparent manner.
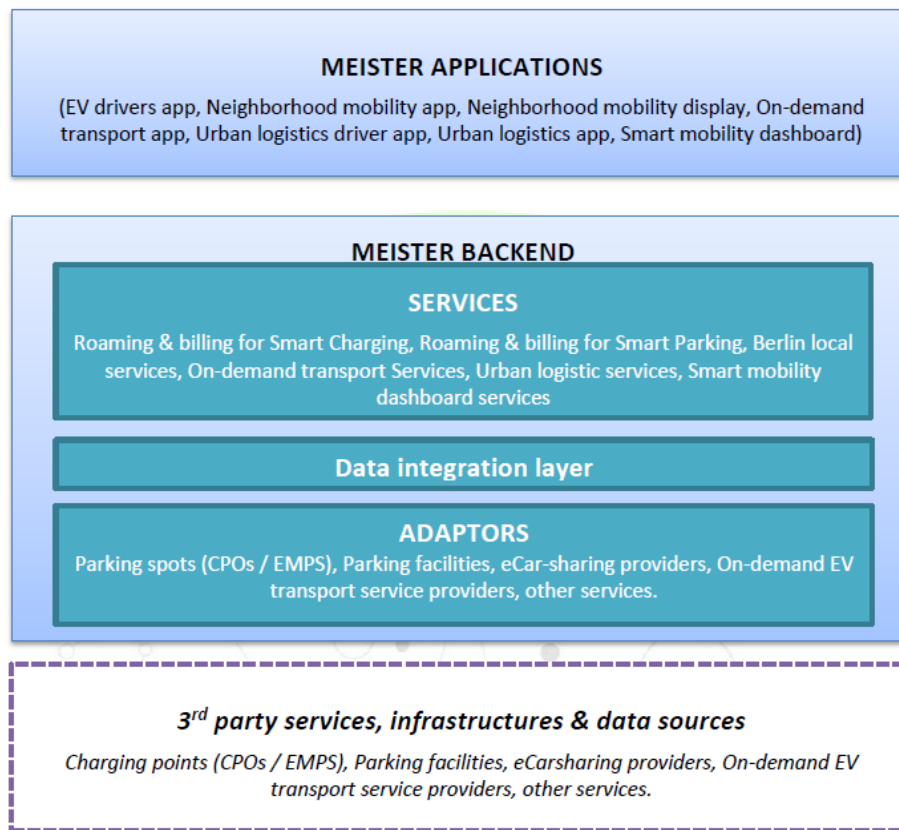
Figure 3. MEISTER Architecture

On the other hand, TwinEV incorporates an algorithm implementing the smart charging of electric vehicles, called *SMArt Charging tool* (SMAC). This algorithm implements smart charging strategies over the Charging Points. SMAC is focused on offering four types of smart charging to drivers. This is possible thanks to four optimal profiles:

- Cheap charge: Maximal energy injection to vehicles when the prices of energy are lower.
- Fast charge: Maximal energy injection to vehicles when more energy is available in the grid.
- Green charge: Maximal energy injection to vehicles when energy is generated by renewable energy sources
- Default charge: Energy model according to restrictions in grid.

Besides, these four profiles, will consider the vehicle-to-grid feature, if user allows it. TwinERGY would additionally allow the testing of the grid operators functionalities as an evolution of the EV management applications. This functionality can manage congestions in grid, since vehicles connected to a charge point can discharge during a time and gives

energy to the overloaded grid. The SMAC algorithm will be described in detail in section 4.6. Smart Charging Tool (SMAC).

According to the objectives and the scope of the TwinERGY project, defined in work packages WP2 and WP4, the components that compose the TwinEV module are depicted in Figure 4:
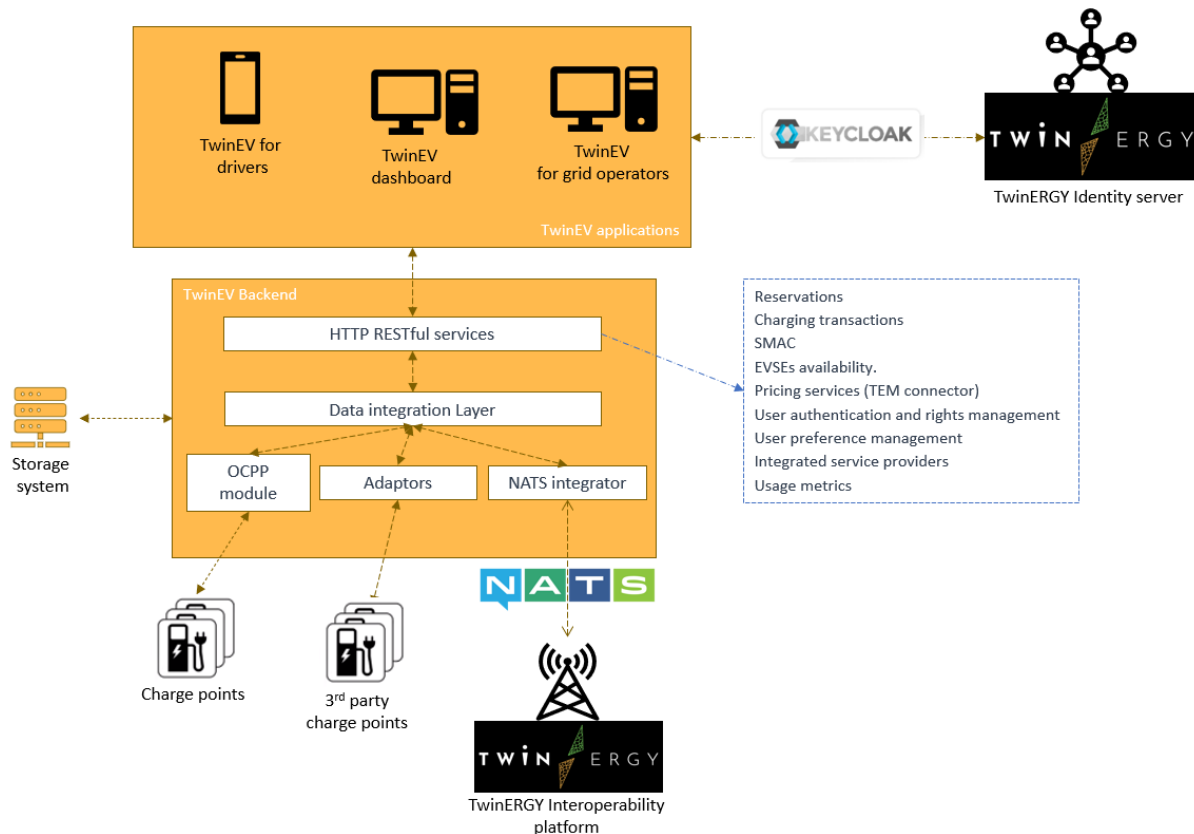
Figure 4. TwinEV architecture

Three applications are placed in the top of the architecture:

- A mobile application for EV drivers. It supports users to different services, such as: help with the selection of a charge station, book a charge point, reserve a shared vehicle, etc.
- TwinEV dashboard, a web application oriented to the management of charge points.
- TwinEV for grid operators, a web application where they can restrict the charge points' supply in case of grid congestions.

These three applications include the communication to the TwinERGY identity server through Keycloak, which allows a unified server to manage users and sessions in all

applications belonging to TwinERGY project. It is described in section 4.5. Auxiliary backend services.

The core of the TwinEV module is the TwinEV backed, directly adapted from Meister. It is supporting the integrated services which are related to the application for individual EV drivers. This application includes components from the backend of Meister, such as: the RESTful API services, the data integration layer or the modules allowing the communication to charge points.

The communication to the rest of modules in WP7, is done through the TwinERGY interoperability server, a NATS server, conforming a messaging tool. A detailed description of NATS technology and the messages interchanged was done in deliverable D7.1.

Finally, the communication to the charging points is given by two channels. One for charging points that are managed directly by TwinEV backend, and another for those that have another manager but are included to the testbed of the project.

4.4 Backend Services

The MEISTER backend is implemented as a huge set of RESTful services supporting their clients with the required functionality. REST is an acronym meaning Representational State Transfer, that is, the transfer of resources, so RESTful is an interface for these transferences from and to a server. A RESTful API is composed by different mechanisms which define how to access these resources, and how to manipulate them. The most common methods in a RESTful API are: 1) GET, getting resources, 2) POST, make modifications over resources, 3) PUT, incorporate new resources, and 4) DELETE, removing resources.

Due TwinERGY project scope, TwinEV will use a reduced set of these services:

- Reservation of charge points, that is, the lock of a charge point during a while in order to start a charge session, and the automatic unlocking of it in case of not using the charging point.
- Management of the start and the end of transactions as well as the monitoring of their status and evolution.
- Control and recording of energy consumption per transaction and in time. This module has been modified in order to incorporate the SMAC, which calculates the corresponding curve for smart charging (see section 4.6. Smart Charging Tool (SMAC)).

- Management and publication of the availability of charge stations.
- Management of pricing & billing, only in local scenarios. Since this feature is implemented through the Transactive Energy Module (TEM) in TwinERGY, the original service will be replaced by another one that communicates to TEM, via the interoperability platform.
- Respect to the interactions with charging stations infrastructure, the CPO is the manager of them. However, it is not defined for German pilot yet, so it will be needed to include an adaptor for it. In any case, all generated transactions done in a Charging Point will be sent to the TEM.

It should be noted that these two latest points have not been implemented during task T7.6, as they correspond to the integration phase. Both will be incorporated during the tasks related to WP8.

4.5. Auxiliary backend services

In addition to services related to EVs, other functionalities are included:

- User authentication and rights management
- User preference management
- Data of the users as customers of the integrated service providers (contracts, terms and condition of usage, preferences).
- Usage metrics, in an anonymized and aggregated way.

According to TwinERGY consortium decision, all modules in WP7 as well as the Digital Twin interface must be offered as a uniform set of tools to users. Taking this into account, these services will be integrated into a common platform managed by Keycloak [5]. Despite that this element is going to be incorporated during the task T8.2, here we expose a short description about what Keycloak is.

Keycloak is a manager of access control based on Single Sign-On (SSO) for web apps and RESTful web services [6]. It means that Keycloak creates a trust relationship between an application (service provider), and an identity provider. This trust relationship is often based upon a certificate that is exchanged.

In a summary, Keycloak is a server to which other applications point to and are secured by it. Browser applications redirect a user's browser from the application to the Keycloak authentication server where they enter their credentials. This redirection is important

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because users are completely isolated from applications and applications never see a user's credentials. Applications instead are given an identity token that is cryptographically signed.

A token is a unique chain of text (an identifier) that represents sensitive data but does not contain any information of that sensitive data, so foreign applications cannot obtain information of the data by only using this token. The sensitive data can be username, address, email, and other profile data. They can also hold permission data so that applications can make authorization decisions. These tokens can also be used to make secure invocations on REST-based services.

4.6. Smart Charging Tool (SMAC)

The SMArt Charging tool algorithm (SMAC) is a smart calculator of profiles of charge for e-vehicles. It considers different inputs not only related to the vehicle features but energy prices, limitations on the grid or predicted RES generation, creating a charge curve adapted to real environment and the type of charge that the user needs in the moment. This is given through these three aspects:

- Supporting of high-value services to EV drivers, such as minimum charging price and maximum RES electricity supply. EV users' preferences and requirements are considered for the definition and customisation of the services.
- Providing smart grid integration services for slow, medium, fast, and ultrafast charging, with the objective of minimising the grid impact associated to the implementation of charging infrastructure.
- Producing flexibility and stabilisation benefits to the DSOs: reduction of the grid impact of new charging infrastructure through demand management, possibility to use EVs as dynamic distributed storage devices, feeding electricity stored in their batteries back into the local electric grid when needed (V2G supply) and flexibility services to the requests of the grid.

Just as a summary, SMAC receives as inputs:

- End-users feedback about the vehicle and the charge (desired maximum time of charge, desired final battery level, etc.)
- grid information (demand, energy prices, production…).
- orders by grid operators

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And it models one charge curve for the period of time that the charge session is active. This charge curve is representing one of the following situations:

1. *Optimum charging profiles considering CPO and driver requirements*: Maximize self-consumption in order to minimise the cost of the energy imported from the grid.
2. *V2G schemes*: Use of EVSEs where Vehicle to Grid (V2G) is possible.
3. *Support to the grid*: This version incorporates modifications on the Charging point power flow to limit it in order to meet the "flexibility orders" given by the DSO.
4. *Trade-off between smart-charge benefits and long-lasting charging sessions*: In the previous modules when only the energy cost is considered in the calculation of the best charging way, some long-lasting charging sessions appear. With this new model, "opportunity costs" are included, so the CPO faces an opportunity cost for every new charge session that cannot be supplied due to the lack of free charging points. This cost increases with the duration of the active sessions, so the algorithm can meet both types of cost (opportunity and energy costs).

Next Figure 5, Figure 6 and Figure 7 show different situations where SMAC calculates the charging profile for charging three vehicles connected to three charge points. For simplification, all vehicles need to be charged in the same maximal time. In all figures, the charts from top to bottom are: energy consumed and produced in the district, energy supplied, charge profiles (SMAC output) and battery status.

As it can be seen in Figure 5, representing a situation in which there are no limitations to the energy injection, vehicles receive more energy in moments where more energy is available, so vehicles have a charge more or less linear

Figure 6, representing a situation with limitations during last part of the charge, shows that SMAC determines to charge vehicles before these limitations.

Figure 7, that is corresponding to having the cheapest energy prices from slot 15 onwards, depicts that SMAC determines to charge vehicles mainly in this time period

As it was commented in section 4.3. General Overview, these models are driven to offer four types of smart charging for TwinERGY project:

- Default charge: Energy model according to restrictions in the grid.
- Cheap charge: Maximal energy injection to vehicles when the prices of energy are lower.
- Fast charge: Maximal energy injection to vehicles when more energy is available in the grid.

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- Green charge: Maximal energy injection to vehicles when energy is generated by renewable energy sources.
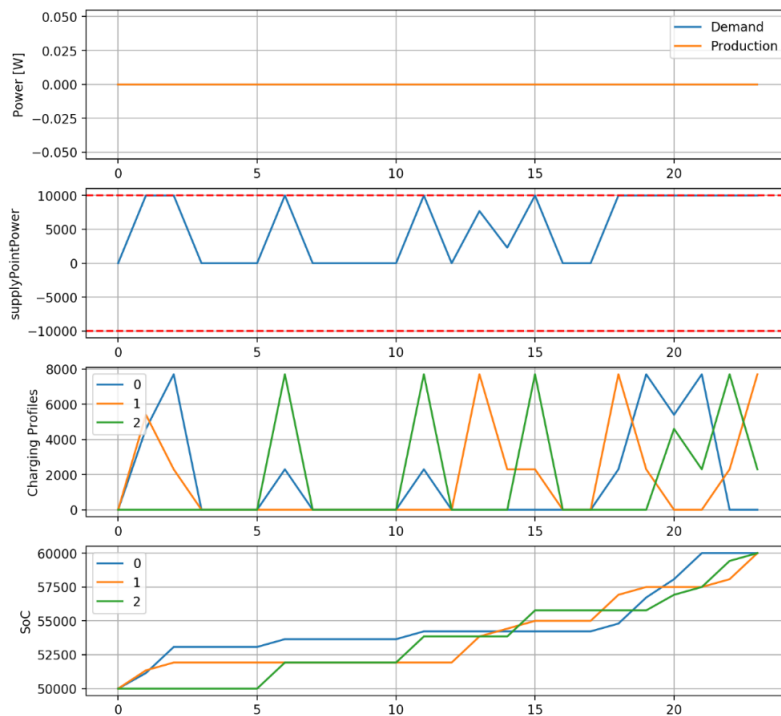
Figure 5. SMAC output for a situation without relevant constraints.

X axis represents the time slot (corresponding to 15 minutes)

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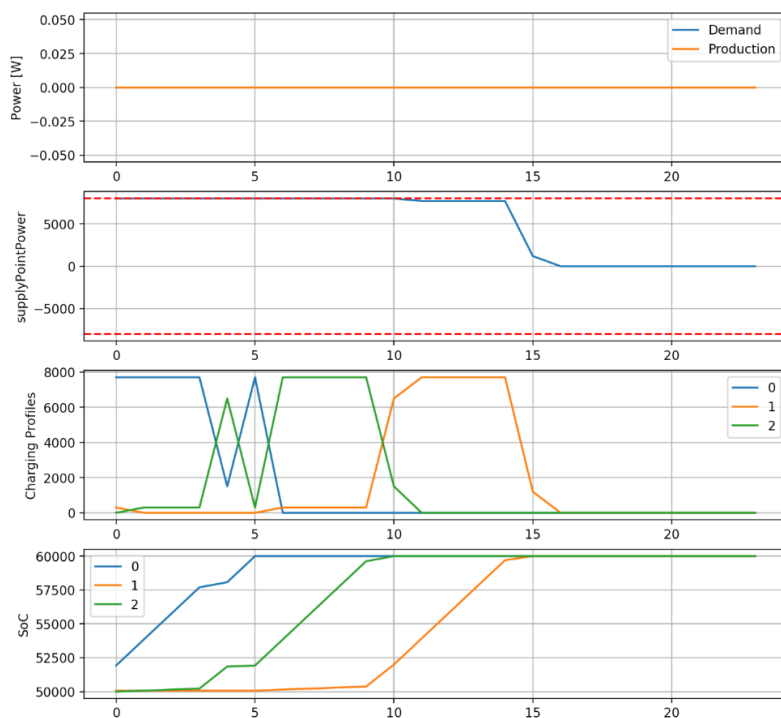
Figure 6. SMAC output considering restrictions ordered by grid operators

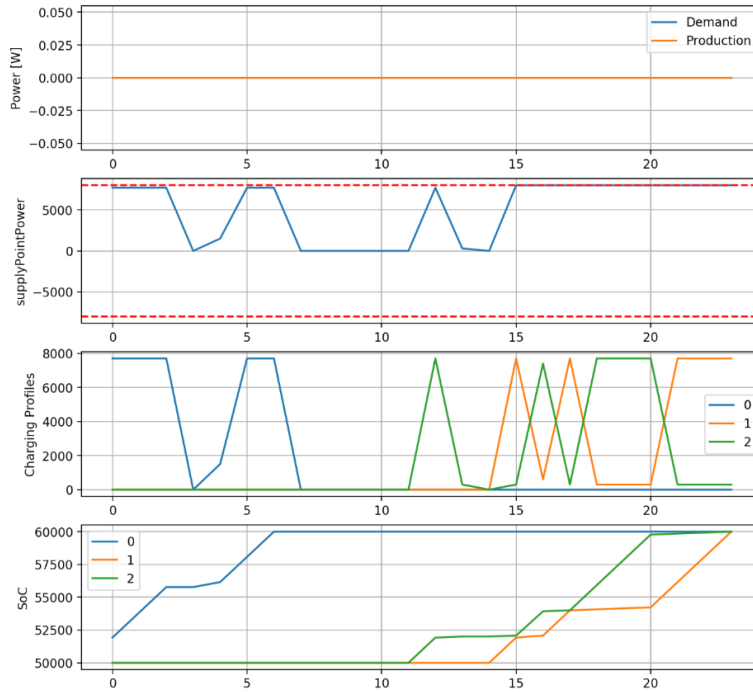*X axis represents the time slot (corresponding to 15 minutes)*

Figure 7. SMAC output considering energy prices

X axis represents the time slot (corresponding to 15 minutes)

5. Data Interchange

As can be deduced from the architecture in Figure 4, the correct functioning of the TwinEV module depends on the interchange of data between the top-placed applications and the backend, the applications and the identity server, the backend and the charge points, and so on. Those data are well formed models that are described in the following sections, as well as the sources of information and the protocols used for the data interchange.

5.1. Data Models

Considering the scope of TwinERGY, we can organize the data models in the following groups:

5.1.1. Related to charging points

The data models considered are:

- CP's static information: location and characteristics like type of connector, maximal power injection or availability of the vehicle to grid features (V2G) in the charging point.
- CP's dynamic data: real-time status of the charging station (EVSEs) and its connectors, availability/reservation status, etc.
- Reservations data: Information about a reservation for starting a charging session.
- CP's data related to charging transactions, prices and applicable tariffs.
- Invoices and accounting, considering the periodic reports on the aggregated cost of the transaction of a period that EMSP are expected to pay to the CPOs, taking into consideration the contractual and commercial (tariffs) applicable.

Since all aspects related to transactions are managed by the TEM, the two last points will be used in the communication to these modules

5.1.2. Related to users

They are used in common backend services and validated by the Identity server:

- Identity (accounts data)
- Privileges
- Preferences
- Contract
- Restrictions, etc.

5.1.3. Related to vehicles

They are used for determining what stations can be used by the driver:

- Charger type
- Battery capacity
- Consumption per km.
- Maximal power
- If it allows vehicle-to-grid

5.1.4. Related to the grid

These types of data model are focused on putting restrictions to the energy injected during a charge and determine the charge profile by the SMAC algorithm:

- Forecasting of demand and production in the neighbourhood and in the district
- Energy mix, the combination of sources of primary energy used in a geographical area.
- Grid operators' restrictions.
- Profile of charge, returned by the SMAC algorithm.
- Energy tariffs and charge session costs.

5.2. Data sources

The TwinEV module will consider different external data sources.

5.2.1. Related to end-users

Data model related to the users' accounts and their identities are sourced by the TwinERGY Identity Server. This server will manage the registration and the sessions in the application. Apart from this, the rights of use of the services by end-users may be affected by regulations. Therefore, some services manage information such as the general conditions of usage of the service or the specific conditions of usage of the service for the user (type of contract or tariff, limitations, etc.)

5.2.2. Related to charging points

The charging points are directly a responsibility of their owners (for private CPs) or the Charging Point Operator (for public or semi-public CPs), so the static and dynamic information related to the CPs is sourced by this role.

The CPO, as an external data source, should provide:

- Existing EVSEs (location and characteristics: types of connectors, power)
- Status of EVSEs in real time: occupancy, reservation, operation condition.
- Status of EVSEs with regards to smart charging the requested and/or real status of a connector: locked, uncharging, etc.
- Reservation of EVSEs: reservation status of each individual charging point, and history of reservations managed (scheduled, active and historic)
- Terms and conditions for usage of the service (see Annex 2. Terms and conditions).
- For smart charging, the availability of the EVSEs for the functionality (technical and operation), metering information and status

5.2.3. Related to the grid

This information is mainly related to the physical environment where the TwinEV module is deployed, so this information is given by external actors, mainly other modules in TwinERGY. A detailed description of this sources was done in deliverable D4.4 – System architecture [7], but the next Table 3 presents the corresponding module to each data loaded

Table 3. Source of data related to grid

Data Input	Origin
RES production forecast in the area	RES Integration & DER Management module
Neighbourhood flexibility profile	Neighbourhood Demand Flexibility Profiling module
Neighbourhood demand forecasting	Neighbourhood Demand Flexibility Profiling module
User appliances flexibility	Consumer Demand Flexibility Profiling module

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Consumer demand forecasting	Consumer Demand Flexibility Profiling module
Local Energy Markets (LEM) pricing	Transactive Energy module
Energy prices	Digital Twin Platform (retrieved from ENTSO-e transparency platform [8])
Energy mix	Digital Twin Platform (retrieved from ENTSO-e transparency platform)
Actual consumption and production	Core Data Management Platform (loaded from real assets at dwellings and common batteries in the district)
Grid restrictions	Input by the grid operator in TwinEV for grid operators

5.3. Outputs

In the opposite side, the information generated by the TwinEV module is loaded by other modules in TwinERGY, stored in the Common Data Management Platform or loaded by Charge points. Table 4 enumerates the destination of the data generated by the TwinEV module.

Table 4. Destinations of data generated by TwinEV module

Data Output	Destination
Charge curve during a session (energy injection or discharging from or to the grid by the vehicle per each slot of time)	CPOs and CPs
Cost of a charge session	Transactive Energy module
Minimal/maxima power to be injected or discharged	CPOs and CPs

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5.4. Protocols and standards

The TwinEV module transfers or retrieves the information cited previously by different protocols of communications and standards used in electromobility as well as in the dialogs among applications. For communication among applications we can ennumerate OpenId, NATS and State of Charge Information, whilst Figure 8 depicts the standards in electromobility. Regardling Figure 8, in the context of TwinERGY the grid operators is not going to communicate directly to the electric mobility service provider, so this link and its protocol (OSCP) is not consider here.The rest of protocols are explained below.
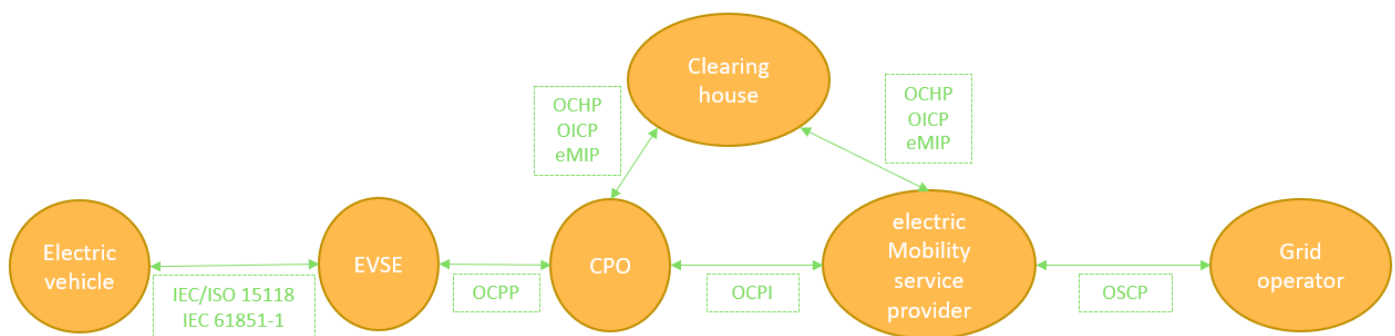

Figure 8. General schema of protocols in electromobility

TwinEV will not consider link between eMSP and Grid operatos

5.4.1. IEC 61851-1 and ISO 15118

Both standards define the communication between the electric vehicle and the charge station.

IEC 61851 is an international standard for electric vehicle conductive charging systems, being one of the International Electrotechnical Commission's [9] group of standards for electric road vehicles and electric industrial. This standard defines the operation for a session charge (from the link with the vehicle to the disconnection after the session end). One of its most important points is the definition of the four charging modes:

1. Direct connection of vehicle to conventional electrical outlets. Focused on electric bikes and scooters.
2. Requires control box between vehicle and electrical outlet, considering slow AC.
3. EVSE permanently connected to electrical grid. Typical public charger installation.
4. Current conversion handled by EVSE, not EV. Focused on fast DC

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Depending on the different countries' legislations some of these modes can be restricted or forbidden. For instance, Mode 2 is not allowed in France.

On the other hand, ISO 15118 is the standard for Vehicle-to-grid communication interface. It defines the bidirectional communication for charging and discharging of batteries in electric vehicles. This standard is used only in situations where both station and vehicle allow this kind of charge, which is available for a reduced subset of EVs. This is the case of chargers implementing the CHAdeMO protocol, which has been invented in Japan and is mainly used for EVs originating from Japanese automotive OEMs. Despite this feature is still reduced in the market, in case of TwinERGY, the German pilot site is going to incorporate a vehicle and one charging point with this feature, so we need to consider this protocol.

5.4.2. OCPP

The Open Charge Point Protocol (OCPP) defines the communication between the charge point management platform (CPO platform) and the e-charging devices. That means that it is the application protocol for communication between the EVSEs and the central management system (also called charging station network). It is an initiative of the ElaadNL [10] in the Netherlands, with the aim of creating an open protocol which allows EV charging stations and central management system from different vendors to communicate with each other. Among other advantages, this protocol reduces the development cost, due the programmers do not need to replicate software for each individual operating system.

Several releases of the protocol exist, with OCPP 1.6 being the first version which allows the control of the charging power at a charging device. An extension of this version, OCPP 1.6 extended, includes the feature of V2G.

5.4.3. OCPI

The Open Charge Point Interface (OCPI) protocol covers the communications among the Charging Point Operator (CPO) and the eMobility Service Provider (EMSP), so it permits EV drivers related to a partner to utilize the chargers of another partner. It has been created in Netherlands by the EVRoaming Foundation [11], with the final goal of allowing any EV driver to charge at any charging station in the EU.

Current functionalities:

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- Roaming peer-2-peer
- Roaming with mixed roles
- Authorization
- Reservation
- Provide tariff information
- Billing
- Provide static charge point information (e.g. location)
- Provide real-time charge point status information
- Provide (real-time) session information
- Provide CDR information
- Remote start/stop (for use via mobile app)
- Smart charging support
- Calibration law (eichrecht) support
- Platform monitoring

5.4.4. OCHP, OICP and eMIP

These three open-source protocols are focused on the roaming, that is, the boundless electric vehicle charging across charging station networks. This allows to drivers to charge their vehicles in different charge stations belonging to different providers abroad.

Open Clearing House Protocol (OCHP) was created in 2012 by partners that launched the e-clearing.net, a German foundation by ElaadNL and smartlab Innovationsgesellschaft mbH.

OICP was designed in 2012 by Hubject - a leading automotive experts in Germany. Hubject offers technical connection and contractual arrangements for e-roaming, so drivers can use different electric stations managed by different providers.

Finally, the eMobility Interoperation Protocol (eMIP) was developed in 2013 in France.

Last but not list, the roaming is included in each electromobility scope, but it is not a characteristic directly considered for TwinERGY.

5.4.5. State of Charge Information

In order to get a successful process of charging (and discharging) of electric vehicles, the knowledge about the level of charge of the battery is needed. For instance, when a vehicle is used for charging, the battery cannot be completely full, and in V2G situations, the

discharge cannot be done if the battery is empty. This level of charge is called "state of charge" (SOC).

However, the SOC is typically not available. Despite NISSAN EVs with bidirectional AME chargers (ame.com) transfer this information by using the OCPP 1.6 extension, most common situation is that charges do not allow this. So, this information is given by the driver before starting a session. In addition, the system needs to know if a vehicle is connected and what type of charger is being used. This knowledge is available on the static "point of interest" (POI).

5.4.5. NATS

As it was cited in section 4.1. Introduction and detailed in deliverable D7.1, all modules in TwinERGY are communicating among them through the Interoperability Platform. This platform consists of a NATS [12] infrastructure, a messaging system where clients send and receive messages following a schema of publication and subscription: Each message is published with a subject so only subscribers to that subject receive the message. The subscriptions can be related to a subject or a subset of subjects, supporting the following features:

- Hierarchies of subjects.
- Send a message and wait for a response.
- Grouping of subscribers in queues.
- Confirmation of message received.
- Inclusion of sequence numbers in messages.

5.4.6. OpenID

Used in the TwinERGY Identity server, OpenID is an interoperable authentication protocol that lets the authentication of users across websites and apps without having to own and manage password files. By authentication we mean the process of establishing and communicating that people operating a browser or native app are who they claim to be. OpenID is easy, reliable, secure, and lets developers get out of the difficult and dangerous business of storing and managing other people's passwords. It is based on OAuth 2.0, a framework specified by the IETF, providing a variety of standardized message flows based on JSON and HTTP.

6. Applications

As it has been commented before, three applications conform the graphical user interfaces in the TwinEV: TwinEV for drivers, TwinEV for grid operators and TwinEV Dashboard. These applications are focused on the different roles of users and they are designed to cover the operation described in the Use Case 03 (HLUC03), "Grid capacity enhancement utilizing e-mobility", which is composed by seven Primary Use case (see deliverable D4.4 [7]):

- PUC03.01. Booking a charge session
- PUC03.02. Smart Charging to follow grid requests
- PUC03.03. Smart Charging to maximize RES integration (green electricity)
- PUC03.04. Smart Charging to minimize charge costs
- PUC03.05. Smart Charging to minimize time of charge
- PUC03.06. Searching of the most suitable station
- PUC03.07. Grid management

Additionally, some extra functionalities need to be considered such as: login, creation of accounts, etc. In the next subsections we explain these applications.

6.1. TwinEV for drivers

This is a mobile application where drivers can reserve charge points, manage their data and receive suggestions about where is better to charge their vehicles. It is an application for smart phones, but it can be managed directly from the browser in other devices such as computers and tablets. The application is accessible through https://twinergy-drivers.tec.etra-id.com/. In case of smart phones, once the user is on the web, he/she can visualize the application in his/her mobile device, considering that depending on the browser version maybe it is needed to force it trough the browser menu. It is available for several languages: English, German, Greek and Spanish.

The user can manage directly the application without logging into it. In this case, the user is able to see a map with available stations and some minimal information about them. For demo purposes, a user has been predefined (user: demo, password Demo_twinergy1).

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The user can log into the application by filling the login form, as can be shown in Figure 9.
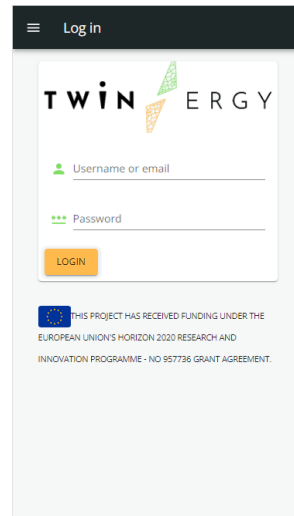

Figure 9. TwinEV for drivers logging interface

After a successful login, the user can access to these screens:

- Search stations and reserve: Searching and status of public charge stations and reservation of charge points during a while for starting a charge session.
- Reserve vehicles: Reservation of shared vehicles in the district
- Reservations: History of reservations done and cancelled
- Charge: management of a charge session
- My profile: management of user profile
- My charging points: Management of private charging points
- My electric vehicles: Management of private vehicles
- Language: configuration of the language

6.1.1. Search stations and reserve

This screen (Figure 10) allows users to get a ranking of public and semi-public stations where he/she can charge, based on four criteria: Basic, green, fast and cheap. The list of shown stations includes only free stations with a charger compatible to the vehicle and closer than the distance marked by the user. Pero each criteria the stations are marked with a colour from red (worst option) to light green (best option), and information about the station appears when it is selected. The user touch on the button "Search" and the map with the stations appears.
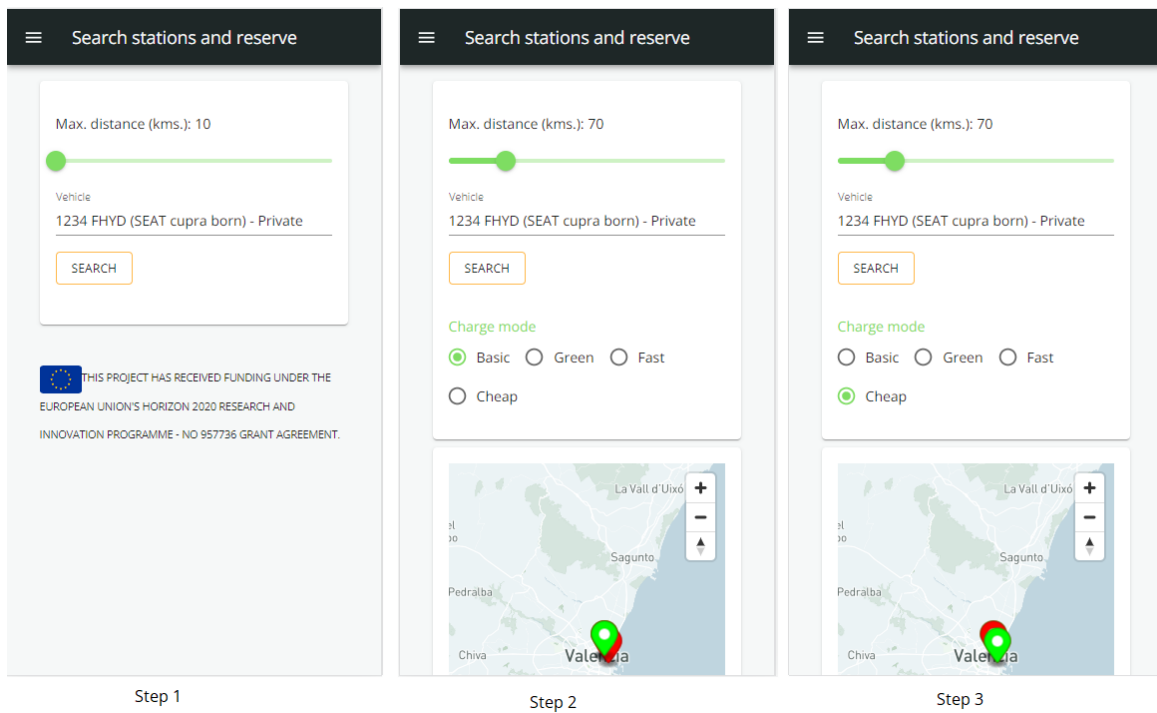
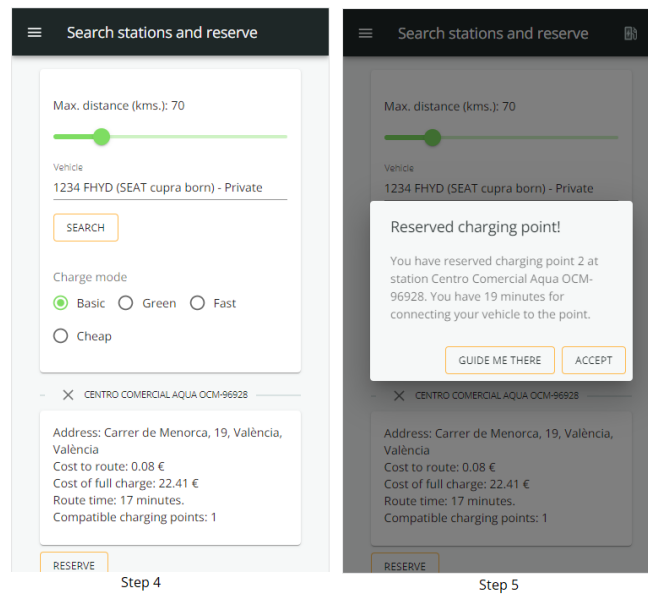*Figure 10. Search stations and reserve screen. Search operations*

Figure 11. TwinEV search stations and reserve. Reservation of charge point

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A station can be selected by touch, and the user can reserve it by touching on button "Reserve". After that a message with the confirmation appears (Figure 11) and a icon indicating that a reservation is active appears in the upper bar ( ). In this dialog, the user can touch on "Accept" or on "Guide me there", so the default maps application in his/her mobile phone will be open with the address of the station. For both options, the TwinEV application will change to Charge screen.

If the user finally does not execute the charge, the reservation will be automatically cancelled after the time indicated in the dialog of Figure 11.

6.1.2. Charge

This screen can be used when a reservation is active or for charging in private charge points, where the reservation is not needed, as the driver owns the charge point. In the first option, the information of the reservation will be shown, in the second option, the user has to configure the session information (Figure 12). For both options, the user has to insert the mode of charge (green, fast, etc), the current battery level, the desired final battery level and the desired session duration (charge time).
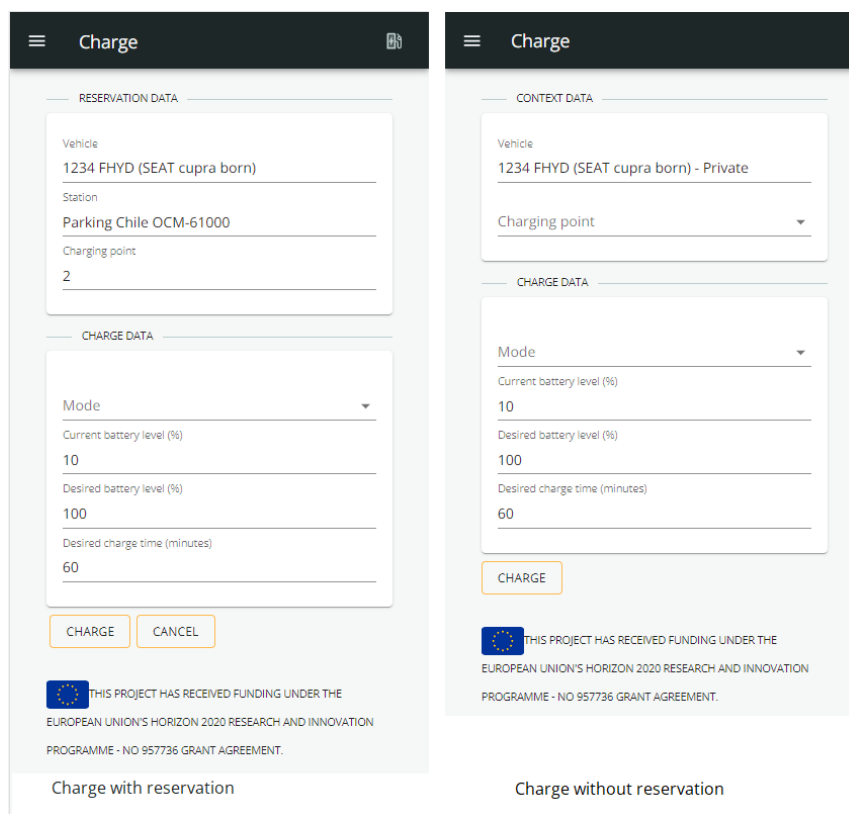

Figure 12. Charge session configuration.

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Left image shows a configuration when a reservation has been done. Right image shows the configuration for a charge in a private point

A reservation can be manually cancelled here or in the screen of "Reservations". Touching the button charge, the session starts (right image in Figure 13) and the new screen shows information about remaining time to finalize the session, the expected battery level, the charge cost in this moment and the energy injected. This information is updated each minute and user can check more detailed information by touching the icon next to it.
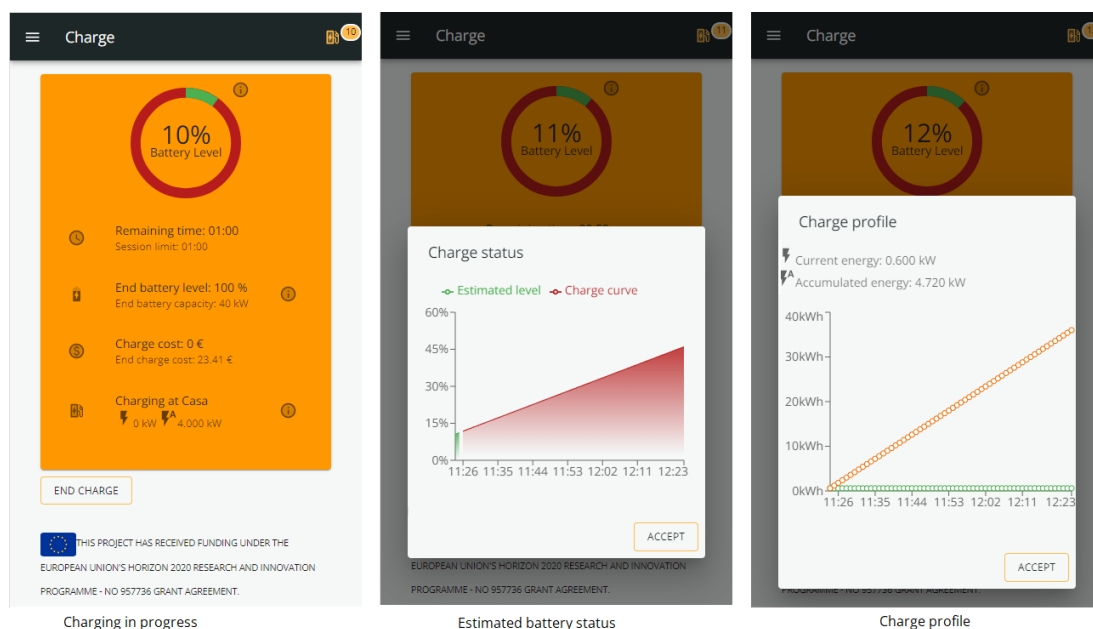

Figure 13. Charge session

Users can stop a charge by touching button "End Charge" or they can wait to the end of the session. In both cases, the screen changes to show a summary (Figure 14). On the right, a session where the user has not picked up his/her vehicle from a public charge point.

For no private charge points, there is a limit to pick up the vehicle, in order to no maintain occupied the lot. If the user does not pick up the vehicle before that time limit, the application starts to apply a penalty (image on the right in Figure 14). When the user wants to pick up the vehicle, he/she touches on button "Pick up vehicle" and the process in ended. Users can close the application or go to another screen. When they return to the charge screen, the information is up to date. Besides, the application shows an icon in the upper bar with the information about the current charge session similar to the blue one, but with different colours: orange when the session is active (with the battery level charged), green when session finished, and red when parking time has been passed.

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| Before exceding parking limit | After exceding parking limit |
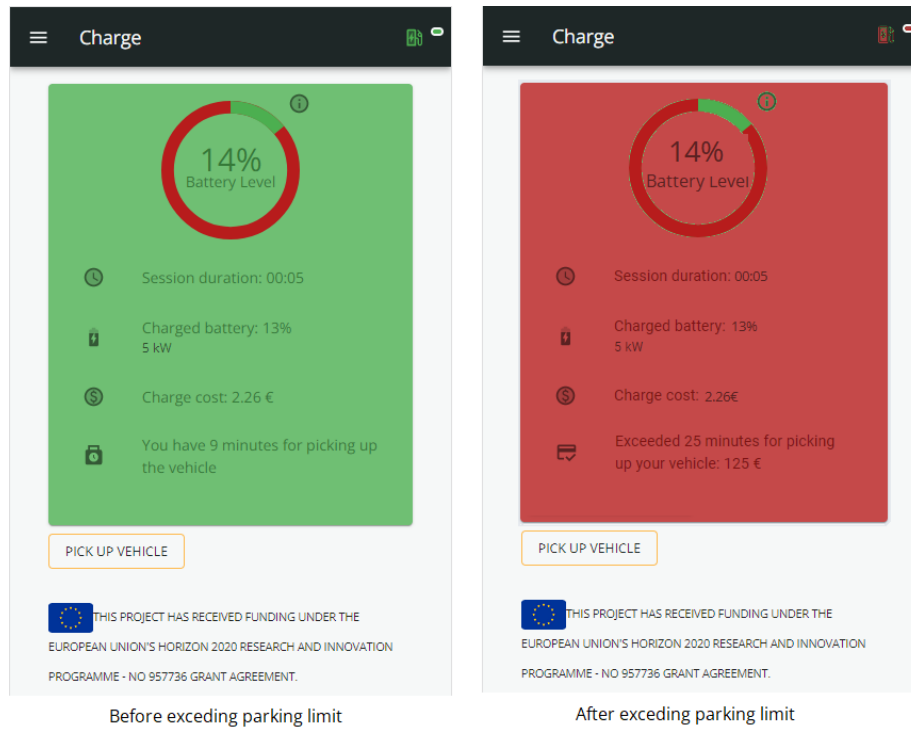
Figure 14. End of charge session.

6.1.3. Reserve vehicles

Despite this functionality was not initially planned for TwinEV, it has been included for being tested in the German pilot, where all users participating on TwinERGY are going to share a vehicle with vehicle-to-grid (V2G) feature. When a vehicle is reserved by a user, it appears as an option for the searching and booking screen and the charge screen. The screen (Figure 15) shows an input for selecting the shared vehicle (in case that more than one vehicle is available in the area) and the charge card to pick up the vehicle.

The user can move over days with the buttons with arrows and touch on "Reserve" to show a dialog for selecting the time slot to have the vehicle. The minimal time to the reservation is two hours in the future. If the reservation has been done successfully, a message of confirmation appears. If not, an error message is shown.

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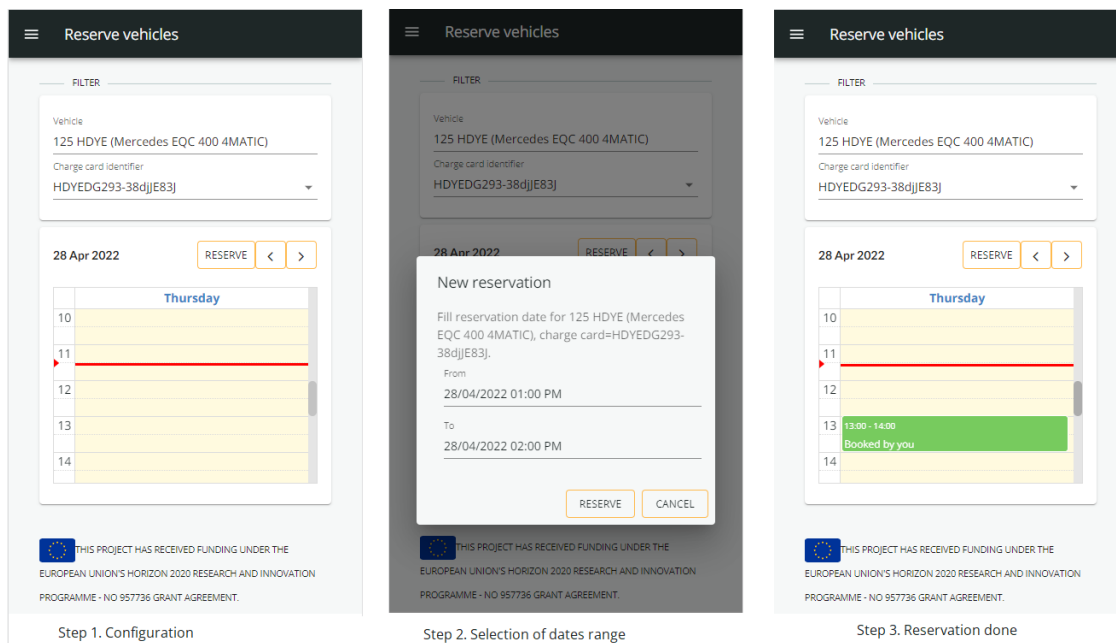
Figure 15. Process for reserving vehicles

6.1.4. Reservations

This screen (Figure 16) is a summary of the operations related to reservations that the user has been done. For each operation the information showed is: Date of the operation, vehicle used, the charging station and the status.

The status of the operation can be:

- Done (if a charge session finished),
- Cancelled: the user cancelled the reservation and not started the charge
- Active: the user has reserved a charging point but the session has not been started
- In use: a charge session is in progress
- Not used: the user reserved a point but finally he/she did not use the point and the system unlock the charge point.

The user can filter his/her reservation by vehicle, charge station and/or status.

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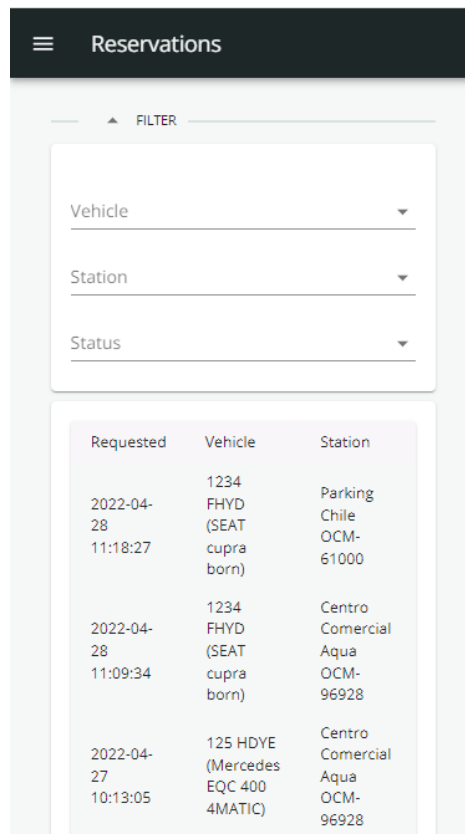
Figure 16. Reservations screen

6.1.5. My profile

Here, user can configure data related to his/her account, in the sense of information that directly TwinEV manages (Figure 17).
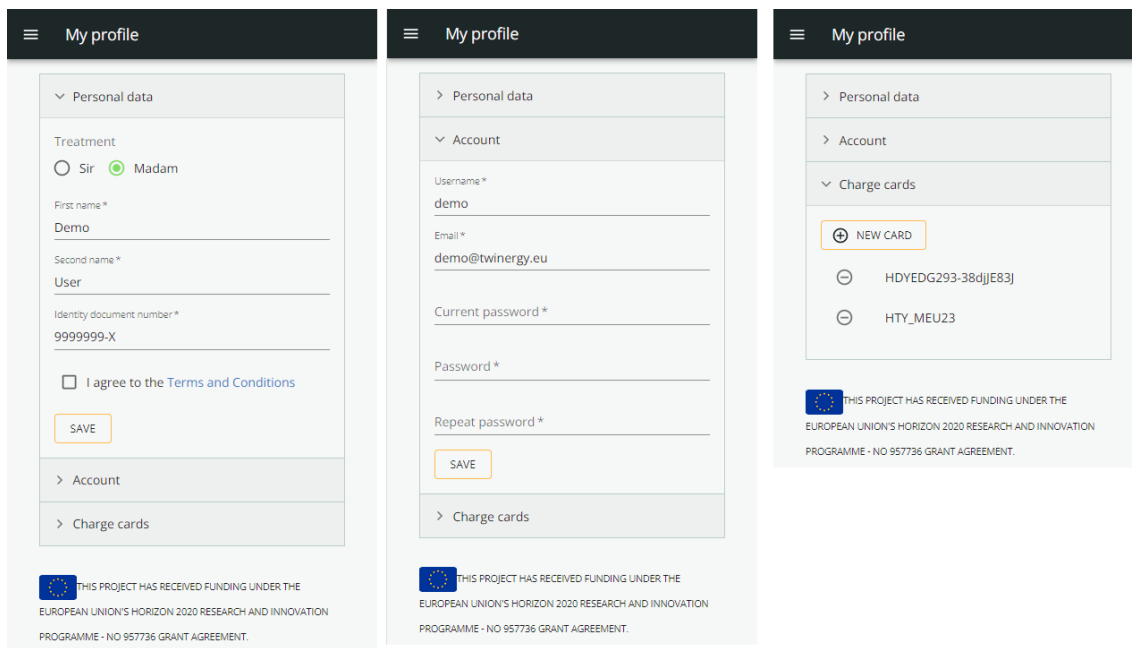
Figure 17. Screen "My profile"

The screen has three sections: one for personal data, another for the account and a third one for the inclusion of charge cards. The section "Account" will be hidden when the TwinEV module is integrated with the rest of modules in TwinERGY project, during tasks of WP8.

6.1.6. My charge points

This screen is focused on the configuration of the private charge points (Figure 18). When an owner wants to use a charge point, he/she only has to include it with this application, so the charge point will be managed by TwinEV backend, being only accessible by the user.

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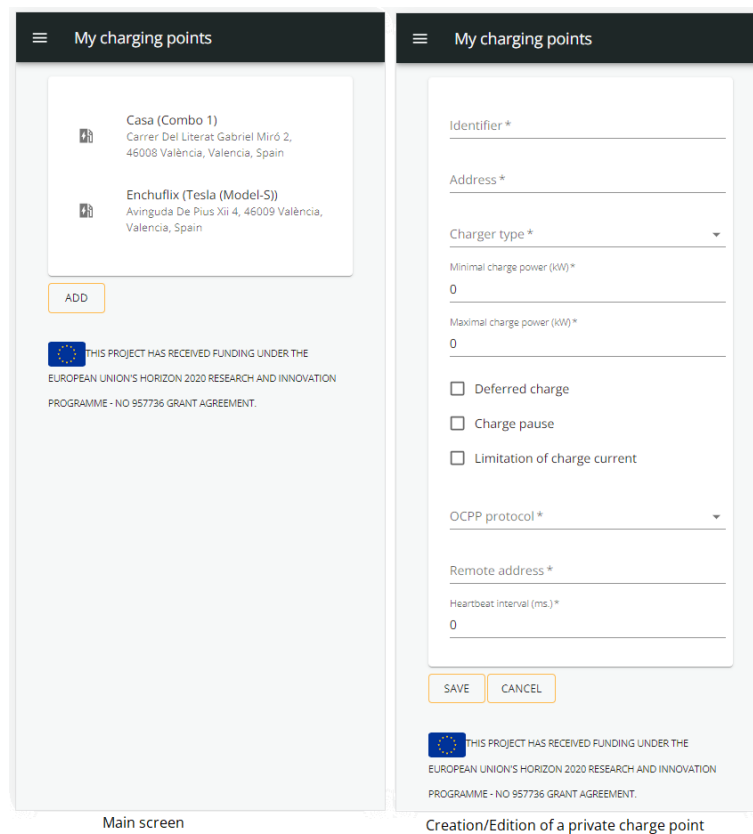
Figure 18. Screen "My charge points" and edition of data

The screen shows the list of charge points owned by the user and a button "Add" for adding a new charge point. Touching on the button or on one of his/her charge points, the screen navigates to a form to insert or modify data related to the new/existing charge point, as can be seen in the previous picture. An existing charge point can be deleted by clicking on the button "Remove".

For the correct configuration of a charging point, the user needs to fill:

- An identifier,
- A postal address
- The charger type, such as SCHUKO, Tesla, etc
- Minimal and maxima power supply
- If the battery allows: deferred charge, charge pause or limitations in the charge
- The OCPP protocol
- The remote address of the charge point (to receive the orders from the CPO)
- The heartbeat interval (for communications)

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6.1.7. My electric vehicles

In a similar screen to the previous one, the user can configure the vehicles that he/she owns (Figure 19). If user does not own any electric vehicle, he/she can reserve a shared vehicle in the area to use the charge functionalities.

Main screen   Creation/edition of an electric vehicle
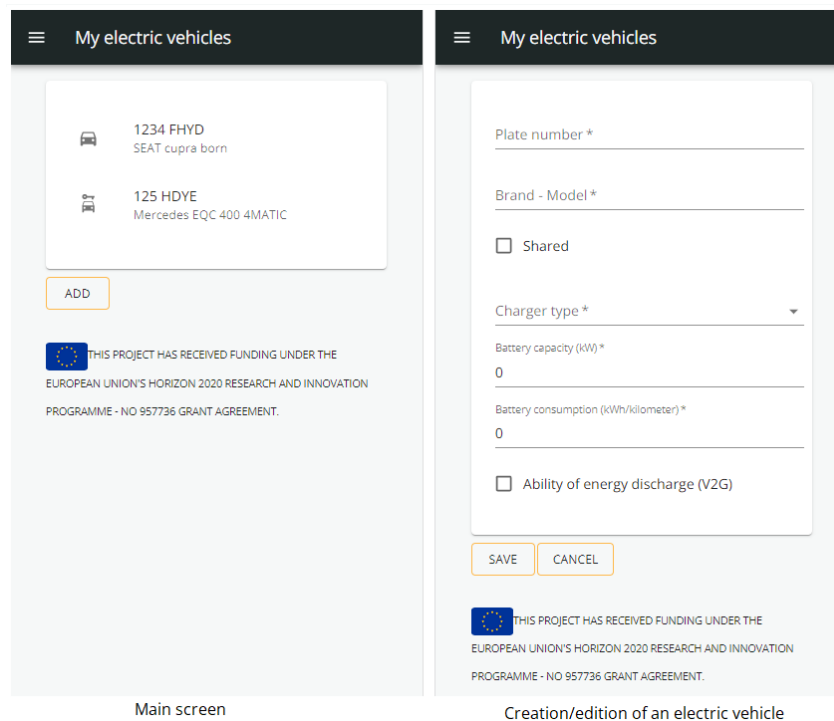
Figure 19. Screen of "My electric vehicles" and related form

The way of work with this screen is the same as the charge points configuration. Button "Add" or touching an item in the list open a form for introducing data related to the new or existing vehicle. The button "Remove" allows to remove an existing vehicle. For each vehicle, the information to be filled is:

- The plate numbers.
- The brand and the model.
- The charger type.
- The minimal and maxima charge power
- The battery capacity
- The battery consumption per kilometre.

Besides, a user can mark the vehicle as shared, so the vehicle can be used by the rest of people in the area, and it appears in the list of shared vehicles in screen "Reserve vehicles". In the main list, vehicles can be marked with two icons: a car for private vehicles and a car with a key for shared vehicles.

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6.2. TwinEV for grid operators

This is a web application where grid operators can set restrictions about the amount of energy to be supplied by selected charge points, in order to manage problems in the grid. The application is available in https://twinergy-grid.tec.etra-id.com/ and one user for demo purposes has been created (username: demo, password: demo). This user can operate over charge points belonging to three aggrupation called "Pruebas Madrid", "Madrid" and "Palma de Mallorca". The application is multilanguage: English, Spanish, German and Greek. The login page is depicted in Figure 20.
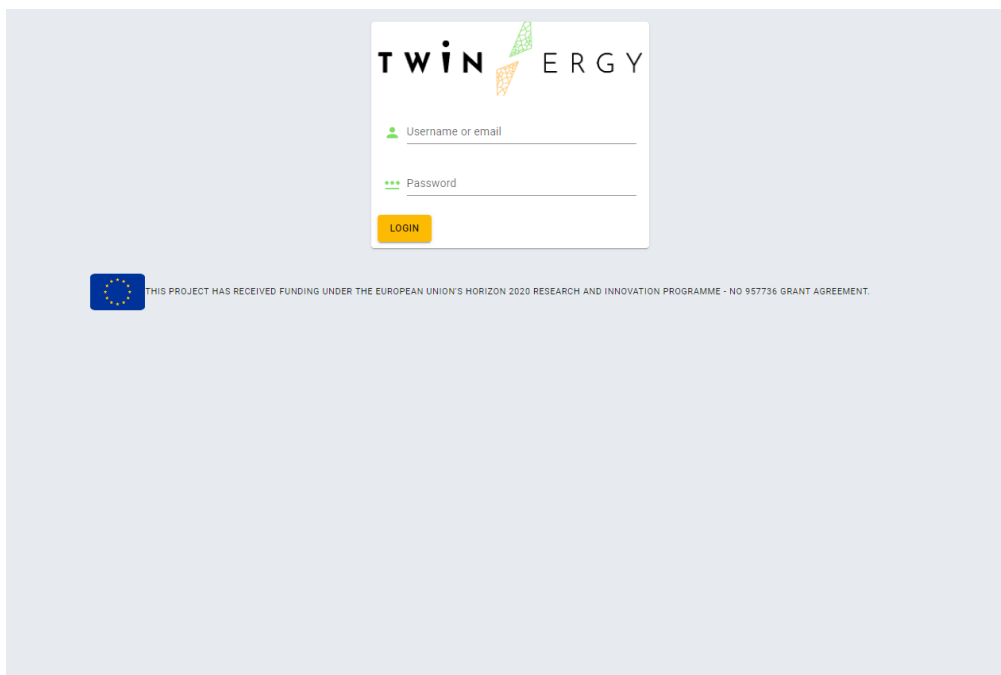
Figure 20. Login page in TwinEV for grid operators.

The application has recognized two user's roles: the grid operator and the administrator. Whilst the grid operator can set restrictions to the charge points, the administrator is able to manage users.

When a user logs into the platform, he/she can access to a single screen for the congestion management. This screen is divided in two views (Figure 21): one for insertion of new restrictions (tab Status) and another one to watch a historical of restrictions in the area (tab Historical). Only administrators can access to a screen for managing users.

![TWIN ERGY logo]

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6.2.1. Charge points map

The tab Status (Figure 21) shows a map with visible charge points, a tool of actions and the form to insert the new restriction. Points in the map are selectable, so when one of them is selected, it appears coloured in yellow.
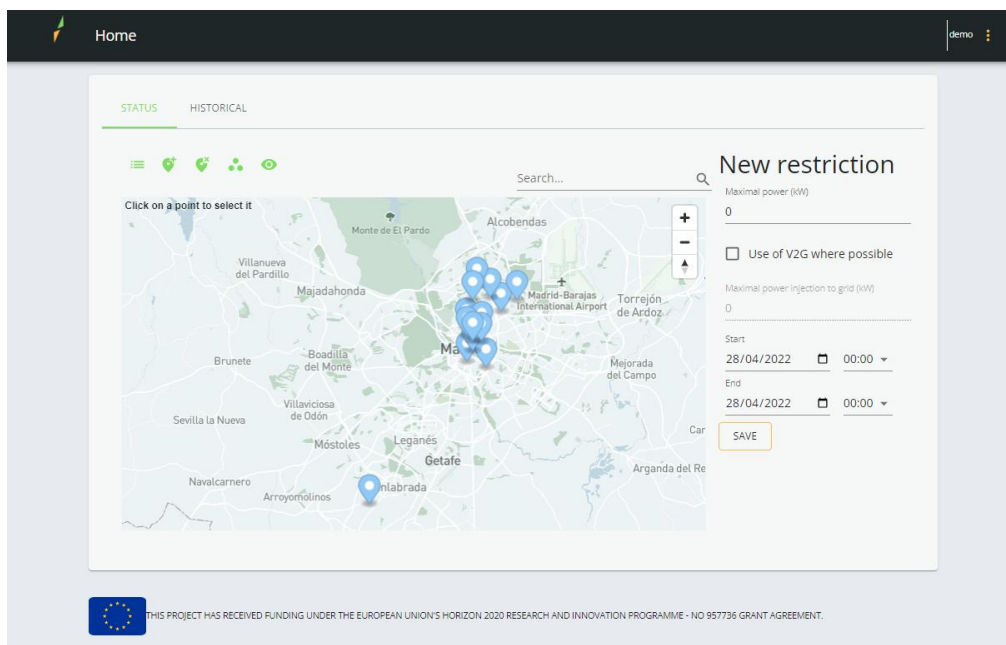
Figure 21. Main screen in TwinEV for grid operators

In order to make easier the selection of the desired charge points, the application shows a toolbar and an input for searching points over the map. The toolbar is composed by the following actions:

- ≣ Show the list of selected points on the left. If the user clicks on one of these points, the map navigates to the point.
- ≣ₓ Hide the list of selected points (when it is visible).
- Select all points in the map.
- Unselect all selected points.
- ⣿ Select/unselect points belonging to one/several group.
- 👁 Hide/show points belonging to one/several groups. This feature is only for visualization, the selection of points is not affected at all.

For these two last actions, the application shows a short dialog with checks where the user selects.

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Next to this toolbar, an input for searching points in the map is offered to users. When a user starts to write, a suggestion of points is shown and in case of user selects one point there, the map navigates to it.
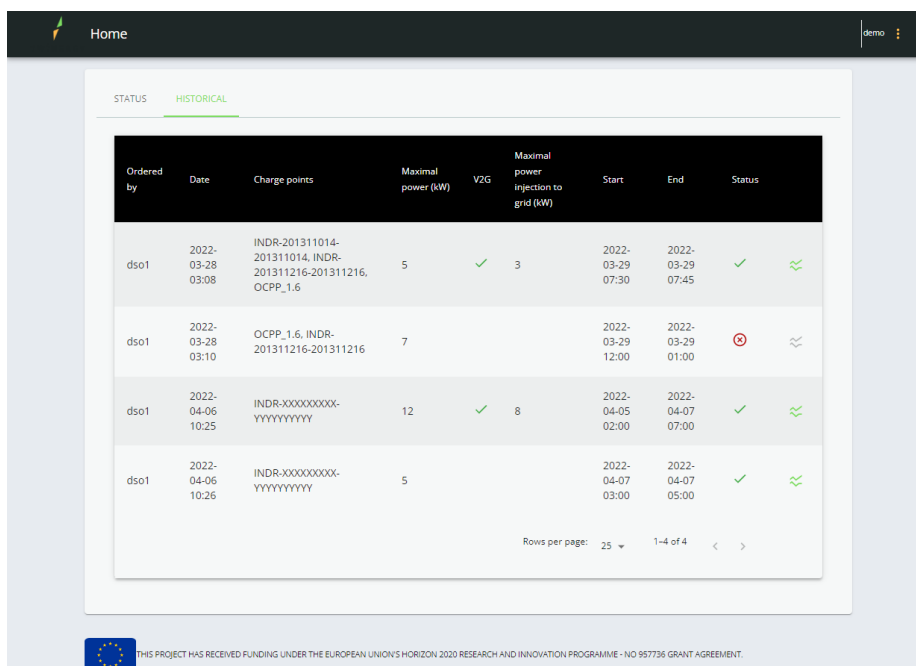
Regarding the restriction itself, the grid operator must insert the following information:

- The maximal power to inject to vehicles
- The use of vehicle-to-grid in points where it is possible.
- The start and the end of the time slot when the restriction is going to be applied.

The restriction will be inserted in the system when the user clicks on the button "Save"

6.2.2. Historical

On the other side, the historical tab (Figure 22) shows a paginated table with the following information: the person who ordered the restriction, the date of the command, the affected charge points, the maximal power injected to vehicles, if includes vehicle-to-grid the start and the end of the period where it is applied and the status of the application: unfeasible or success. If a restriction is unfeasible means that it was not possible to create a charge curve appropriated for the limit indicated.

Figure 22. TwinEV for grid operators. Historical

For restrictions that could be applied the application can show the charge profile calculated by SMAC algorithm. Clicking on button ≋, a window with some charts appears

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in the browser like in Figure 23. The charts are: the charge profile for batteries (in case that they are consider in the district), the charge profile for charge points and the flexibility estimated

Figure 23. Charge profile calculated with restriction

6.2.3. Management of users

As commented, a user with the role of administrator can manage users, so he/she can create, remove and modify users, and assign them the groups of charge points that they manage. This screen is available through option "Users" in upper menu, and it has the appearance of next Figure 24.
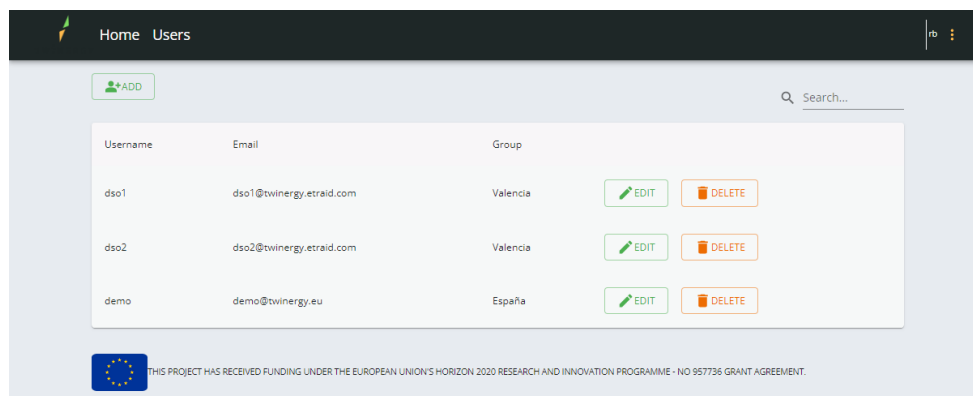
Figure 24. Management of users

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Each registered grid operator appears in the table, where the username, the email and the group of stations assigned to the user. Clicking in button "Add" or in button "Edit" opens a dialog for edit the data corresponding to the new or the existing user (Figure 25). The dialog is the same for both cases, but just in case of adding a user the input for the password are visible. The change of password is only allowed to the own user, so the administrator is not able to modify it.

The user's data are:

- Username
- Email
- Group of charge points to be managed. A group can be composed by subgroups and they by another groups. Therefore, the groups in the dialog are not presented like a list but a tree of groups. If a group is selected, the grid operator will be able to manage charge points belonging to any of the groups in the brand selected.
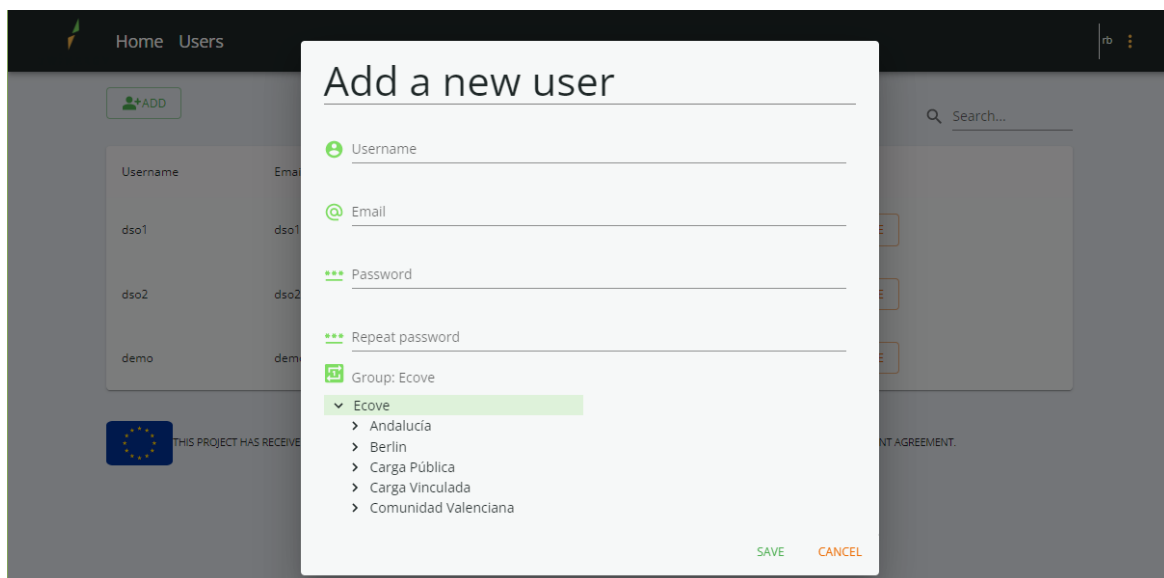
Figure 25. Dialog for create/edit users

6.3. TwinEV dashboard

This is a web application where charge points managers can manage their charge stations. The application is available in https://twinergy-dashboard.tec.etra-id.com/ and one user for demo purposes has been created (user: demo@twinergy.eu, password: prueba). It is a multilanguage application.

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Once the user has been logged in the application, the default screen to be watched is the map of the charging points. On the left, a chart with the status of the stations appears (percentage of currently charging). Despite each point in the map has a title, clicking on it, a dialog with detailed information is shown.

The rest of screens are described below.

Figure 26. Main screen in TwinEV dashboard

6.3.1. Transactions

This screen shows a paginated table where current and past transactions are listed (Figure 27). Each transaction represents a transaction of energy between a charge point and an electric vehicle. It includes this information:

- Operation identifier.
- Status: Active (charging in progress), Completed (charge finished),
- Total energy injected to the vehicle
- Token of the driver
- Charge station and Charger identifiers
- Last update

Figure 27. TwinEV dashboard. Transactions page

If the user clicks on the icon 👁, a dialog with the transaction's details is shown (Figure 28), including a chart with the progression of the energy delivered.
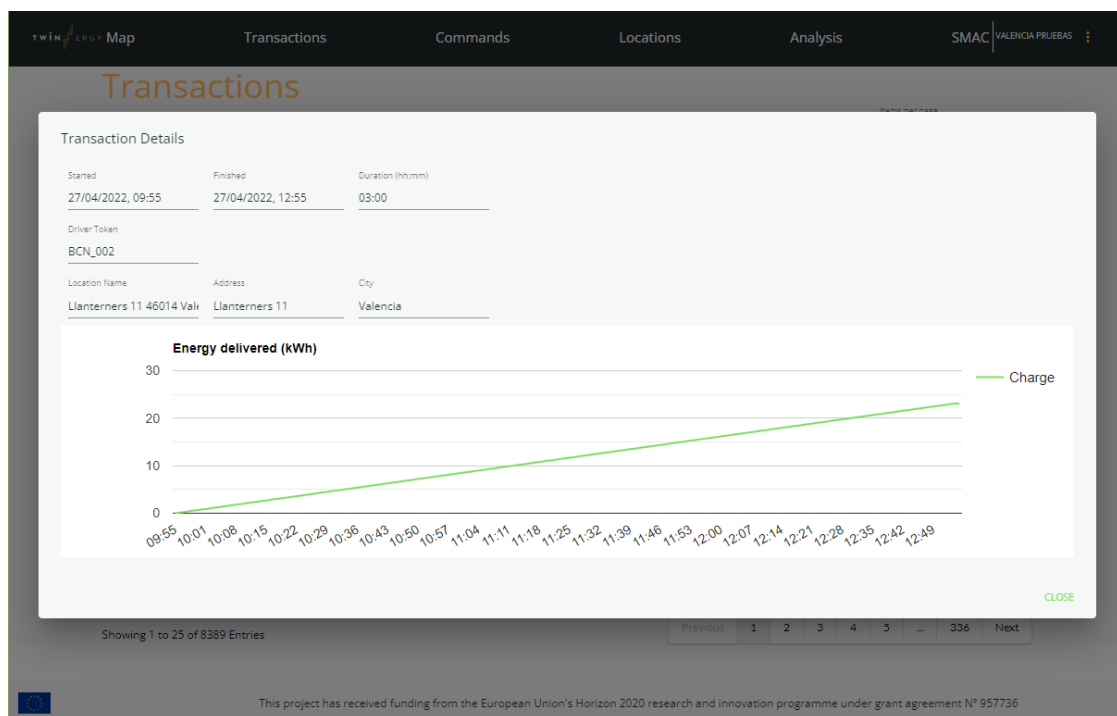
Figure 28. TwinEV dashboard. Details of a transaction

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6.3.2. Commands

This screen (Figure 29) shows a paginated table of commands sent to each charge point from mobile application for drivers. Commands can be: start or end a charge session, reserve a charger, cancel a reservation, unlock a charger and so on.
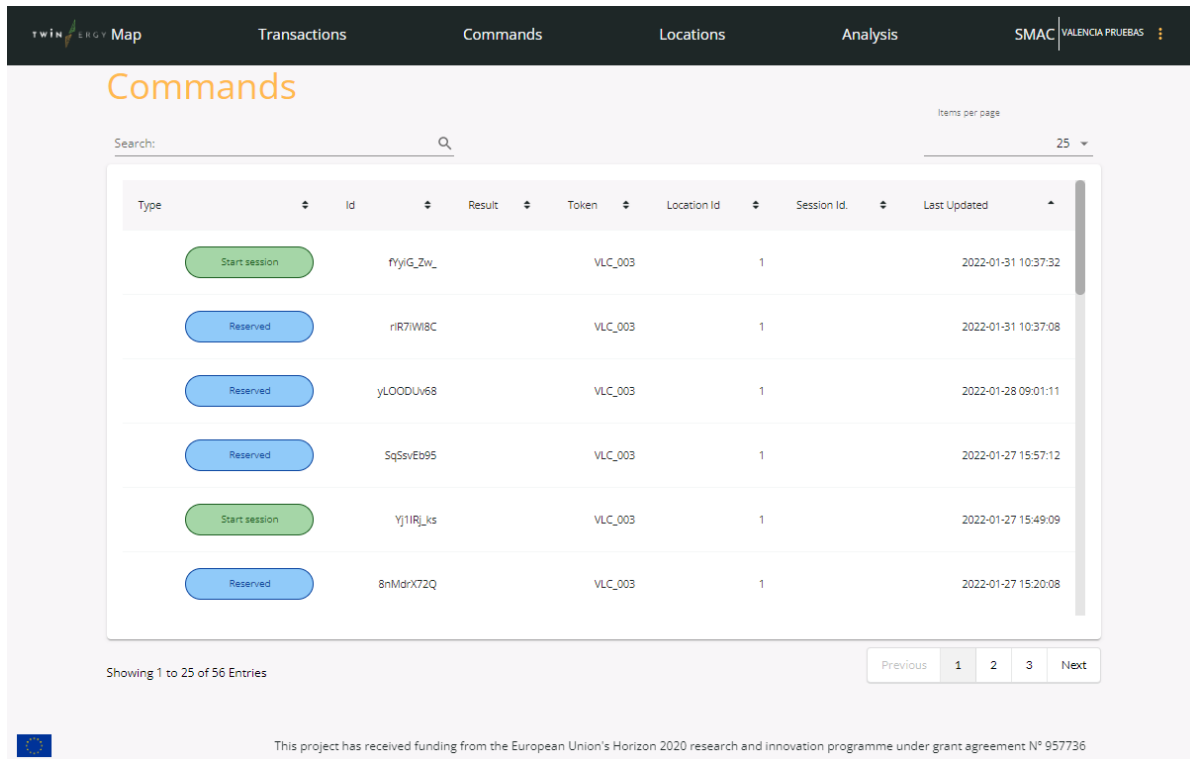
Figure 29. TwinEV dashboard. Commands

For each command listed, the information is: the type, the identifier, the result of the operation (if needed), some identifiers of the charger and the station and the last updated.

6.3.3. Locations

This screen informs about technical aspects of each charge station and its chargers, and the smart charge profiles calculated by SMAC (Figure 30). The screen is divided on two tables: one for the charge stations and another one for smart charge profiles.

The charge stations table shows the following information: The charge station information identifiers, the capabilities of the station (commands allowed), the status and the last update of information. The status is one of those described for the view

Commands. Besides, clicking on button ⊙ makes visible a dialog with detailed information of the charge point and its connectors.

The optimization context table shows the list of current restrictions over the charge points are active. These restrictions can be set here and not only by grid operators in the previous application. An optimization context is formed by Supply point contracted capacity, a supply point injection limit, the local storage capacity and the opportunity cost.
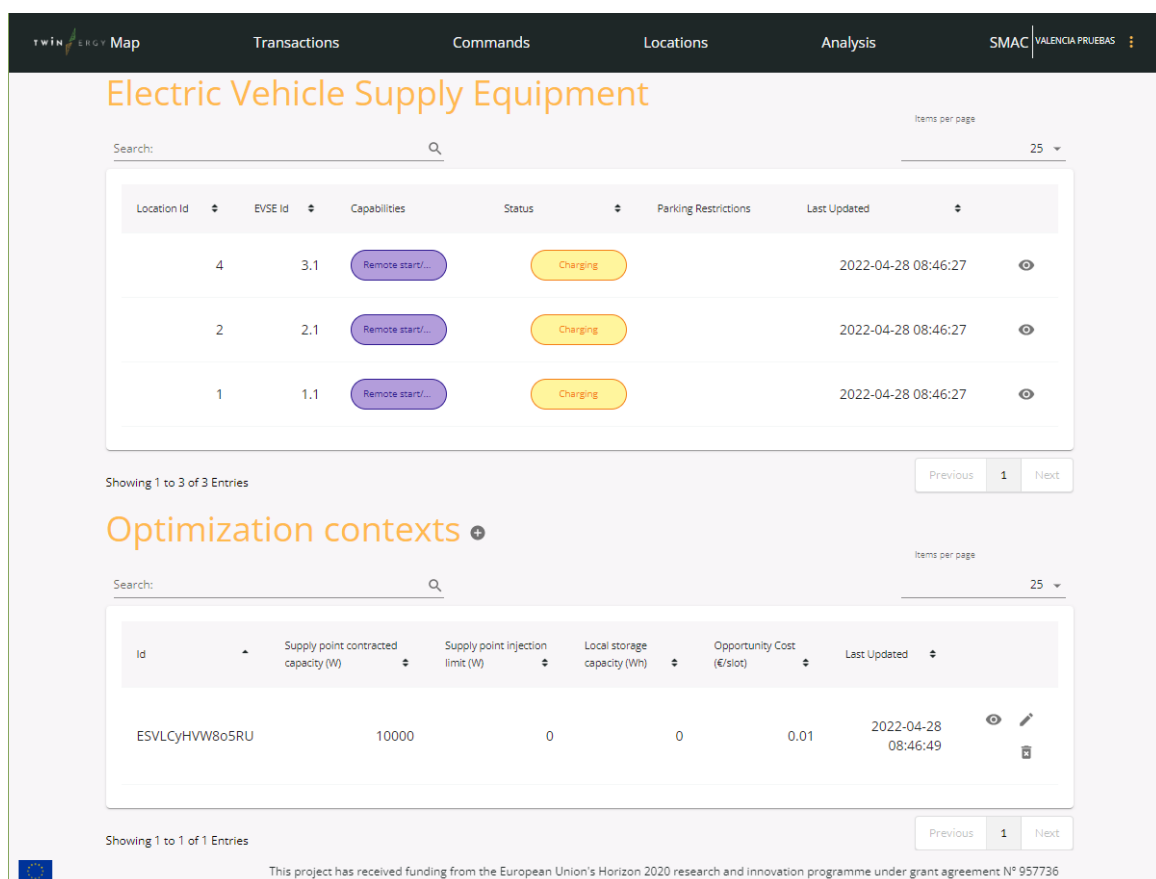
Figure 30. TwinEV dashboard. Locations.

6.3.4. Analysis

This screen shows statistics about the use of the charge points for the selected month (Figure 31). If the selected month is the current one, the information is related to the past days in the month. The displayed information is a summary on the left and a set of charts on the right. The summary contains:

- The total number of transactions

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- The total energy supplied to vehicles
- Average session duration
- Average energy supplied per session

And the charts are

- Daily number of transactions
- Daily energy delivered
- Percentage of transactions per station
- Percentage of energy supplied per station
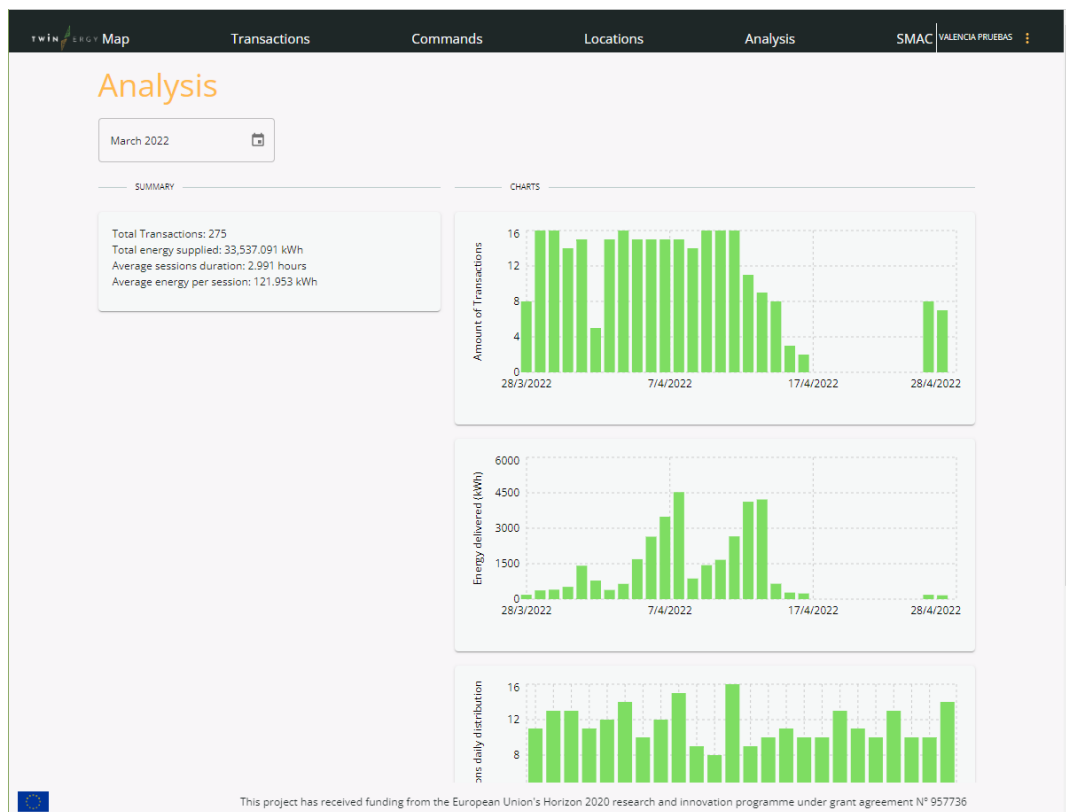
Figure 31. TwinEV dashboard. Analysis

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7. Deployment and Testing

A first prototype of TwinEV module has been deployed and tested in an isolated way. As in this phase of the project, the integration with the rest of components in TwinERGY project is in an early status, a complete testing has not been done yet. In this section we present the actions and solution for the deployment as well as the test plan.

7.1. Deployment

The TwinEV module and its applications have been deployed in ETRA premises, using Docker [13] technology. Docker is a modern open-source project that automatizes and makes easier the deployment of applications, since it organizes applications in a kind of virtual boxes called "containers", integrating all requirements and dependencies needed. Each container is isolated from the rest of the containers, but containers can communicate with each other through channels.

In addition to the advantage of simplicity in deployments, regarding the maintenance and the requirements in installations, Docker containers are a lighter solution in comparison to have traditional configurations like several servers or several virtual machines (VMs). Virtual machines contain a complete operative system over all software is installed, so in case of having different applications that have different needs, we should maintain and configure several virtual machines. For instance, in traditional solutions, a system administrator could create, configure and maintain one server/VM for the database, another one for storage system, another for the set of applications, etc.

Figure 32 shows a comparison between an installation of several applications/engines/databases with Docker, several servers and Virtual Machines. As it can be seen, docker is lighter and easier to maintain than the other solutions. Of course, in a real environment for the sake of security and scalability, we have different servers in a real environment, such as: a server for applications, a server for services, a third server for files storing and a fourth one for databases. However, this is hard to configure and maintain, because administrators must be sure that they install the adequate operative system for each machine depending on the software to be installed, and secure each of them. An updating of the software needs to check the different versions and reinstall them.

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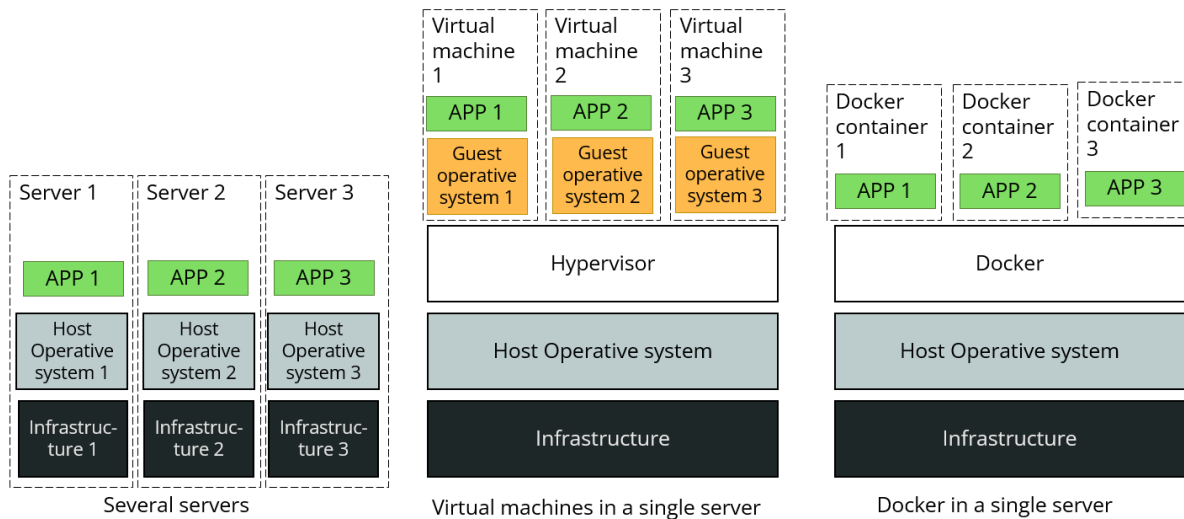
Figure 32. Virtual machines vs. Docker

Virtual machines can solve in part the previous situation, but we still have to maintain each complete guest operative systems hosted in the server, and be careful with the actualizations, dependences and securities.

In case of Docker, the administrator is sure that docker is including in the container only the needed dependences. Updating of applications is totally automated, so developers do not need to be worried about dependencies or the operating system over which the application is going to be running.

As we have commented, TwinEV components (applications and database) are deployed in different Docker containers. This allows us to update applications easily and the rest of applications still are accessible online even during an installation/updating. Besides, in case of problems with the current server we can easily transfer containers to another server which has installed docker, with a single configuration file.

7.2. Testing

As it is well known, during the development and deployment of a product or service, or the installation of a hardware component, testing is essential in order to ensure the quality of the produced results. The testing is not a final step, after the final integration, but it has to be introduced during all the life cycle of a project.

During the development of the TwinEV components, a long set of lab tests has been executed, with the aim of ensuring that actions are executed as it is expected. Actions here correspond to: the result of pressing a button, show the correct subset of data on a

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list/table depending on the filter given by the user, store correctly the information when it is saved, etc.

In testing, we can consider several kinds of tests, being the following ones, the most important:

- Component Testing: Per each internal element in a software component, it involves the testing of multiple functionalities as a single code and its objective is to identify if any defect exists after connecting those multiple functionalities with each other.
- Functional Testing: This type of testing ignores the internal parts and focuses only on the output to check if it is as per the requirement or not. It is a Black-box type testing geared to the functional requirements of an application.
- Usability Testing: The main goal is to know if a new user can understand the application easily or not.
- Accessibility Testing: Related to usability, it is focussed on determining whether the software or application is accessible for disabled people or not.
- Vulnerability Testing: The testing identifies weaknesses in the software code.

Note that not all these kinds of tests are considered for every single module, because they have no sense in some situations. For instance, accessibility is not taken into account in TwinEV dashboard.

Each test case is documented in a table like next Table 5.

Table 5: Test case template

TEST_CODE. Unique name of the test	
Module under test	The module to be tested
Elements validated	The requirement, use case, or certification rule which is validated by the test case.
Features to be tested	List of features to be tested
Preconditions (optional)	List of conditions needed for the test execution
Previous steps (optional)	Shortlist of steps needed for preparing the test environment for test execution

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Dependencies (optional)	List of test case codes defining test cases which need to be passed before the test case at hand can be started
Steps	Testing procedures
Postconditions	Status after the execution of the test
Acceptance criteria	Expected (measurable) results, allowing to unambiguously judge if the test is passed or not passed (i.e. the product requirement was validated or not validated)
Suspension criteria (Optional)	Conditions under which continuation of the test is considered pointless because testing results would be invalid

As the list of tests is huge and since TwinEV module has been designed with the goal of covering the primary use cases related to electric vehicles in TwinERGY (Use case 03), we expose in this deliverable only the set of test cases that are focused on cover those use cases. The list of test cases is given in the next table. The test cases templates can be read in Annex.

Table 6. List of test cases

Identifier	Name	Module
TWINEV_DRVR_1	Searching of charge points in an area	TwinEV for drivers
TWINEV_ DRVR_2	Reservation of a public charge point	TwinEV for drivers
TWINEV_ DRVR_3_1	Start a charge session of a reserved charge point (grid requests)	TwinEV for drivers
TWINEV_ DRVR_3_2	Start a charge session of a reserved charge point (RES integration)	TwinEV for drivers

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TWINEV_ DRVR_3_3	Start a charge session of a reserved charge point (RES integration - v2g)	TwinEV for drivers
TWINEV_ DRVR_3_4	Start a charge session of a reserved charge point (minimal charge costs)	TwinEV for drivers
TWINEV_ DRVR_3_5	Start a charge session of a reserved charge point (charge time)	TwinEV for drivers
TWINEV_ DRVR_4	Start a charge session of a private charge point	TwinEV for drivers
TWINEV_ DRVR_5	Manual stop of a charge session	TwinEV for drivers
TWINEV_ DRVR_6	Automatic stop of a charge session	TwinEV for drivers
TWINEV_GRD_1	Add a new restriction	TwinEV for grid operators
TWINEV_GRD_2	Check a restriction effect	TwinEV for grid operators
TWINEV_DSHB_1	Transactions	TwinEV dashboard
TWINEV_DSHB_2	Commands	TwinEV dashboard
TWINEV_DSHB_3	System statistics reflecting actions by drivers and grid operators	TwinEV dashboard

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8. TwinEV in Pilots

The TwinEV module is going to be integrated in Greek and German pilot sites, as the other two do not include the electromobility problem. Both Greek and German pilot include the electromobility as a part of the complete set of use cases covered, but each one is considering different features of this field. In the next sections we expose the characteristics of each one and the role of TwinEV there.

8.1. German pilot

This pilot is placed in the village of Hagedorn in Steinheim, located in North Rhine-Westphalia. It is integrated by 38 houses with 103 inhabitants. The site is connected to the medium voltage grid and supplied with electricity by two local network stations. So, problems related to a big or national electrical grid infrastructure are not considered.

Regarding the electromobility, the pilot site is going to include an electric vehicle that will be shared by neighbours and one public charge point, including the vehicle-to-grid feature.

The charge point considered in this demo site as well as the integration features of this pilot are described in deliverable D8.1. However, as a summary, the communication with the charge point will be directly using the OCPP Module (see Figure 4).

Lastly, the responsible of the German pilot, TH-OWL, will test the combination of bidirectional charging of electric cars with its energy management system.

Therefore, in this pilot TwinEV module is used for covering:

- Sharing of vehicles among neighbours.
- Smart charging considering vehicle-to-grid feature.
- Management of congestions in a local grid.

8.2. Greek pilot

This pilot site is placed in Athens, involving a group of residential and commercial buildings that belongs to the clientele of MYTILINEOS. This demo site is focusing on engaging local consumers in implicit Demand response programs. For that, one of the

aspects to be considered is the use of electric charge information in order to include them in their analysis for those programs.

The Greek pilot includes a set of charge points, public or domestic, and different electric vehicles. However, the vehicle-to-grid is not considered. The communication with the charge points will be done with both OCPP module and adaptors.

According to the goals of this demo site, TwinEV will cover the next features:

- Smart charging without vehicle-to-grid.
- Management of congestions in the distribution grid.
- Demand response campaigns

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9. Conclusions

This deliverable has included a complete description of the TwinEV module, its rationale in the TwinERGY project, architecture and problems covered by it.

The deliverable exposes the results of the work carried out under Task 7.6 "TwinEV Module", whose aim is to design and develop a module that provides high-value services to EV users.

During the Task 7.6, the work has included the design, implementation, testing and deployment of several components belonging to the TwinEV module, such as: TwinEV for drivers, TwinEV for grid managers or TwinEV dashboard.

As well, this deliverable describes how the module will be used in the Greek and German pilot.

Finally, this deliverable stablishes the plan test for the module in those pilots.

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Annexes

Annex 1. Test cases

TWINEV_DRVR_1. Searching of charge points in an area	
Module under test	TwinEV for drivers
Elements validated	PUC03.06. Searching of the most suitable station
Features to be tested	• Retrieve a list of charge points according to the user needs • Help user to decide what is the best station to choose
Preconditions (optional)	1) The user has to be logged into the application. 2) The user has configured a private vehicle or book a shared vehicle for the time of the search.
Previous steps (optional)	
Dependencies (optional)	
Steps	1. Open the view "Search station and reserve" 2. Place the slider marker of "Max. distance" to 30 kms. 3. If more than one vehicle is enable, select one in the selector "Vehicle". 4. Press button "Search" 5. Wait for the visualization of the map 6. Change between the different options of "Charge mode" 7. Touch one of the stations represented in the map.
Postconditions	• After step 4, a map is visible and contains a set of charge points in different colours. • After step 6, the stations change their colours, depending on the criteria selected • After step 7, information about the charge point is showed

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	• None of the charge points marked have incompatible connectors.
Acceptance criteria	All the postconditions are met
Suspension criteria (Optional)	The map is not represented. None of stations is represented in the map or none alert informing is shown. None information of each station is shown

TWINEV_ DRVR_2. Reservation of a public charge point	
Module under test	TwinEV for drivers
Elements validated	PUC03.01. Booking a charge session
Features to be tested	• Reservation of charge points
Preconditions (optional)	1) The user has to be logged into the application. 2) The user has configured a private vehicle or book a shared vehicle for the time of the search.
Previous steps (optional)	
Dependencies (optional)	TWINEV_DRVR_1
Steps	1. After have the list of stations on the map, touch the greenest one. 2. Press the button "Reserve" 3. In the dialog, press "Accept"
Postconditions	• After step 2, a dialog indicating the information about the reservation is visible. The dialog indicates the charger in the station and the limit of time to connect the vehicle • After the step 3, the app navigates to screen Charge. • A blue icon in the toolbar appears indicating that a reservation is active

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	• The charge view shows the reservation data
Acceptance criteria	All the postconditions are fulfilled.
Suspension criteria (Optional)	One or several postconditions is not fulfilled

TWINEV_ DRVR_3_1. Start a charge session of a reserved charge point (grid requests)	
Module under test	TwinEV for drivers
Elements validated	• PUC03.02. Smart Charging to follow grid requests
Features to be tested	Booking of a station Smart charging to follow grid requests
Preconditions (optional)	1) The user has to be logged into the application. 2) The user has configured a private vehicle or book a shared vehicle for the time of the search. 3) The user has reserved a charge point with a charger compatible with the vehicle
Previous steps (optional)	
Dependencies (optional)	TWINEV_ DRVR_2, Information about the status of the grid has to be know, in order to check if the profile calculated is correct
Steps	1. Open screen "Charge" 2. Select mode "Basic" 3. Fill the current battery level with a positive value 4. Fill the desired battery level with a positive value 5. Insert 120 minutes as desired charge time 6. Press button "Charge" 7. When the information card appears, press the button of information next to the energy supplied data.
Postconditions	• The charge starts

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	• The form hides and an orange card with information about the charge appears • The information showed in the card corresponds to the data filled in the form • The information is updated each minute • After step 7, a dialog with a charge curve appears
Acceptance criteria	All the postconditions are fulfilled and the charge curve and profiles charts correspond to the variations on the grid.
Suspension criteria (Optional)	Any of the postconditions fails or the charts has no sense for the grid situation

TWINEV_ DRVR_3_2. Start a charge session of a reserved charge point (RES integration)	
Module under test	TwinEV for drivers
Elements validated	• PUC03.03. Smart Charging to maximize RES integration (green electricity)
Features to be tested	Booking of a station Smart charging to maximize charge when the RES production is maximal
Preconditions (optional)	1) The user has to be logged into the application. 2) The user has configured a private vehicle or book a shared vehicle for the time of the search. 3) The user has reserved a charge point with a charger compatible with the vehicle
Previous steps (optional)	
Dependencies (optional)	TWINEV_ DRVR_2, Information about the status of the grid has to be known, in order to check if the profile calculated is correct
Steps	1. Open screen "Charge" 2. Select mode "Green"

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	3. Fill the current battery level with a positive value 4. Fill the desired battery level with a positive value 5. Insert 120 minutes as desired charge time 6. Press button "Charge" 7. When the information card appears, press the button of information next to the energy supplied data.
Postconditions	• The charge starts • The form hides and an orange card with information about the charge appears • The information showed in the card corresponds to the data filled in the form • The information is updated each minute • After step 7, a dialog with a charge curve appears
Acceptance criteria	All the postconditions are fulfilled and the charge curve and profiles charts correspond to the maximization of RES generation
Suspension criteria (Optional)	Any of the postconditions fails or the charts are not corresponding to RES generation

TWINEV_ DRVR_3_3. Start a charge session of a reserved charge point (RES integration - v2g)	
Module under test	TwinEV for drivers
Elements validated	• PUC03.03. Smart Charging to maximize RES integration (green electricity)
Features to be tested	Booking of a station Smart charging to maximize charge when the RES production is maximal
Preconditions (optional)	1) The user has to be logged into the application.

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	2) The user has configured a private vehicle or booked a shared vehicle for the time of the search, having v2g enabled. 3) The user has reserved a charge point with a charger compatible with the vehicle, having v2g enabled.
Previous steps (optional)	
Dependencies (optional)	TWINEV_ DRVR_2, Information about the status of the grid has to be known, in order to check if the profile calculated is correct
Steps	1. Open screen "Charge" 2. Select mode "Green" 3. Fill the current battery level with a positive value 4. Fill the desired battery level with a positive value 5. Insert 120 minutes as desired charge time 6. Press button "Charge" 7. When the information card appears, press the button of information next to the energy supplied data.
Postconditions	• The charge starts • The form hides and an orange card with information about the charge appears • The information showed in the card corresponds to the data filled in the form • The information is updated each minute • After step 7, a dialog with a charge curve appears
Acceptance criteria	All the postconditions are fulfilled and the charge curve and profiles charts correspond to the maximization of RES generation, including moments where the vehicle is drain energy to the grid
Suspension criteria (Optional)	Any of the postconditions fails or the charts are not corresponding to a RES generation preference, including intervals where the vehicle is draining energy to the grid.

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TWINEV_ DRVR_3_4. Start a charge session of a reserved charge point (minimal charge costs)	
Module under test	TwinEV for drivers
Elements validated	• PUC03.04. Smart Charging to minimize charge costs
Features to be tested	Booking of a station Smart charging to minimize the cost of the session
Preconditions (optional)	1) The user has to be logged into the application. 2) The user has configured a private vehicle or booked a shared vehicle for the time of the search. 3) The user has reserved a charge point with a charger compatible with the vehicle
Previous steps (optional)	
Dependencies (optional)	TWINEV_ DRVR_2, Information about the energy prices has to be known, in order to check if the profile calculated is correct
Steps	8. Open screen "Charge" 1. Select mode "Cheap" 2. Fill the current battery level with a positive value 3. Fill the desired battery level with a positive value 4. Insert 120 minutes as desired charge time 5. Press button "Charge" 6. When the information card appears, press the button of information next to the energy supplied data.
Postconditions	• The charge starts • The form hides and an orange card with information about the charge appears • The information showed in the card corresponds to the data filled in the form • The information is updated each minute • After step 7, a dialog with a charge curve appears

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Acceptance criteria	All the postconditions are fulfilled and the charge curve and profiles charts correspond to the minimization of session cost
Suspension criteria (Optional)	Any of the postconditions fails or the charts are not corresponding to the cheapest energy prices

TWINEV_ DRVR_3_5. Start a charge session of a reserved charge point (charge time)	
Module under test	TwinEV for drivers
Elements validated	• PUC03.05. Smart Charging to minimize time of charge
Features to be tested	Booking of a station Smart charging to minimize the charge time
Preconditions (optional)	1) The user has to be logged into the application. 2) The user has configured a private vehicle or booked a shared vehicle for the time of the search. 3) The user has reserved a charge point with a charger compatible with the vehicle
Previous steps (optional)	
Dependencies (optional)	TWINEV_ DRVR_2, Information about the grid status has to be known, in order to check if the profile calculated is correct
Steps	1. Open screen "Charge" 2. Select mode "Fast" 3. Fill the current battery level with a positive value 4. Fill the desired battery level with a positive value 5. Insert 120 minutes as desired charge time 6. Press button "Charge"

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	7. When the information card appears, press the button of information next to the energy supplied data.
Postconditions	• The charge starts • The form hides and an orange card with information about the charge appears • The information showed in the card corresponds to the data filled in the form • The information is updated each minute • After step 7, a dialog with a charge curve appears
Acceptance criteria	All the postconditions are fulfilled and the charge curve and profiles charts correspond to the minimization of session time
Suspension criteria (Optional)	Any of the postconditions fails or the charts are not corresponding to highest injection of energy when highest energy production and lowest energy consumed

TWINEV_ DRVR_4. Start a charge session for a private charge point	
Module under test	TwinEV for drivers
Elements validated	• PUC03.02. Smart Charging to follow grid requests • PUC03.03. Smart Charging to maximize RES integration (green electricity) • PUC03.04. Smart Charging to minimize charge costs • PUC03.05. Smart Charging to minimize time of charge
Features to be tested	Smart charging in private charge points
Preconditions (optional)	1) The user has to be logged into the application. 2) The user has configured a private vehicle or booked a shared vehicle for the time of the search. 3) The user has configured a private charge point with a charger compatible with the vehicle

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Previous steps (optional)	
Dependencies (optional)	
Steps	1. Open screen "Charge" 2. Select vehicle 3. Select the charge point 4. Select one mode of charge 5. Fill the current battery level with a positive value 6. Fill the desired battery level with a positive value 7. Insert 120 minutes as desired charge time 8. Press button "Charge" 9. When the information card appears, press the button of information next to the energy supplied data.
Postconditions	• The charge starts • The form hides and an orange card with information about the charge appears • The information showed in the card corresponds to the data filled in the form • The information is updated each minute • After step 9, a dialog with a charge curve appears
Acceptance criteria	All the postconditions are fulfilled and the charge curve and profiles charts correspond to the criteria selected
Suspension criteria (Optional)	Any of the postconditions fails or the charts are not corresponding to the mode of charge selected

TWINEV_ DRVR_5. Manual stop of a charge session	
Module under test	TwinEV for drivers
Elements validated	• PUC03.02. Smart Charging to follow grid requests • PUC03.03. Smart Charging to maximize RES integration (green electricity) • PUC03.04. Smart Charging to minimize charge costs

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	• PUC03.05. Smart Charging to minimize time of charge
Features to be tested	Smart charging in private charge points
Preconditions (optional)	1) The user has to be logged into the application. 2) The user has configured a private vehicle or booked a shared vehicle for the time of the search. 3) The user has configured a private charge point with a charger compatible with the vehicle
Previous steps (optional)	The user has started a charge session
Dependencies (optional)	TWINEV_ DRVR_3_1, TWINEV_ DRVR_3_2, TWINEV_ DRVR_3_3, TWINEV_ DRVR_3_4, TWINEV_ DRVR_3_5, TWINEV_ DRVR_4
Steps	1. Open screen "Charge" 2. When the information card appears, press the button of "End charge"
Postconditions	• The charge stops • The orange card changes its colour to green • The information showed in the card corresponds to the real information of the session • If the charge point is public, a message of minutes for picking up the vehicle is shown
Acceptance criteria	All the postconditions are fulfilled
Suspension criteria (Optional)	Any of the postconditions fails

TWINEV_ DRVR_6. Automatic stop of a charge session

Module under test	TwinEV for drivers
Elements validated	• PUC03.02. Smart Charging to follow grid requests

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	• PUC03.03. Smart Charging to maximize RES integration (green electricity) • PUC03.04. Smart Charging to minimize charge costs • PUC03.05. Smart Charging to minimize time of charge
Features to be tested	Smart charging
Preconditions (optional)	1) The user has to be logged into the application. 2) The user has configured a private vehicle or booked a shared vehicle for the time of the search.
Previous steps (optional)	The user has started a charge session
Dependencies (optional)	TWINEV_ DRVR_3_1, TWINEV_ DRVR_3_2, TWINEV_ DRVR_3_3, TWINEV_ DRVR_3_4, TWINEV_ DRVR_3_5, TWINEV_ DRVR_4
Steps	1. Open screen "Charge" 2. Wait the time indicated for the session duration.
Postconditions	• The charge stops • The orange card changes its colour to green • The information showed in the card corresponds to the real information of the session • If the charge point is public, a message of minutes for picking up the vehicle is shown
Acceptance criteria	All the postconditions are fulfilled
Suspension criteria (Optional)	Any of the postconditions fails

TWINEV_GRD_1. Add a new restriction	
Module under test	TwinEV for grid operators
Elements validated	• PUC03.02. Smart Charging to follow grid requests • PUC03.07. Grid management

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Features to be tested	Grid management
Preconditions (optional)	1) The user with role grid operator has to be logged into the application. 2) The user has assigned some charge points
Previous steps (optional)	
Dependencies (optional)	
Steps	1. Go to tab "Status" 2. Select one or several points in the map, by clicking them or with the selection by groups 3. Fill the form on the right. 4. Click on "Save" 5. Close the info message 6. Change to tab "Historical" 7. Check the table
Postconditions	• A new item appears in the table, corresponding to the created restriction
Acceptance criteria	A confirmation message appears after step 5. The new restriction is on the table and its information is what user filled
Suspension criteria (Optional)	The confirmation message did not appear or the restriction is not in the table.

TWINEV_GRD_2. Check a restriction effect	
Module under test	TwinEV for grid operators
Elements validated	• PUC03.07. Grid management
Features to be tested	Grid management
Preconditions (optional)	1) The user with role grid operator has to be logged into the application.

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	2) The user has assigned some charge points
Previous steps (optional)	Successful execution of previous test case
Dependencies (optional)	TWINEV_GRD_1
Steps	1. Go to tab "Historical" 2. Go to the row corresponding to the restriction created in previous test case 3. Click on the icon to open the charts dialog
Postconditions	• A dialog with charts corresponding to flexibility and charge profiles appears
Acceptance criteria	The dialog is open and the charts reflect the limit for the energy injected during the period of time when the restriction is active
Suspension criteria (Optional)	The dialog is not open or the charts do not reflect the limit for the energy injected during the period of time when the restriction is active

TWINEV_DSHB_1. Transactions	
Module under test	TwinEV dashboard
Elements validated	• PUC03.02. Smart Charging to follow grid requests • PUC03.03. Smart Charging to maximize RES integration (green electricity) • PUC03.04. Smart Charging to minimize charge costs • PUC03.05. Smart Charging to minimize time of charge
Features to be tested	Visualization of charge points status
Preconditions (optional)	1) The use has to be logged into the application. 2) One user in "TwinEV for drivers" application is making actions related to charge sessions
Previous steps (optional)	

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Dependencies (optional)	•
Steps	1. Go to screen "Transactions" 2. Check the table
Postconditions	• The table is updating in real time and showing all the current actions related to charges
Acceptance criteria	The table shows reliable information
Suspension criteria (Optional)	The table does not update the information in real time

TWINEV_DSHB_2. Commands	
Module under test	TwinEV dashboard
Elements validated	• PUC03.01. Booking a charge session • PUC03.02. Smart Charging to follow grid requests • PUC03.03. Smart Charging to maximize RES integration (green electricity) • PUC03.04. Smart Charging to minimize charge costs • PUC03.05. Smart Charging to minimize time of charge • PUC03.07. Grid management
Features to be tested	Visualization of commands sent to charge points
Preconditions (optional)	1) The use has to be logged into the application. 2) One user in "TwinEV for drivers" application is making actions related to charge sessions 3) One user in "TwinEV for grid operators" application is setting restrictions to the charging points
Previous steps (optional)	
Dependencies (optional)	
Steps	1. Go to screen "Commands" 2. Check the table

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Postconditions	• The table is updating in real time and showing all the current actions related to commands
Acceptance criteria	The table shows reliable information
Suspension criteria (Optional)	The table does not update the information in real time

TWINEV_DSHB_3. System statistics reflecting actions by drivers and grid operators	
Module under test	TwinEV dashboard
Elements validated	• PUC03.02. Smart Charging to follow grid requests • PUC03.03. Smart Charging to maximize RES integration (green electricity) • PUC03.04. Smart Charging to minimize charge costs • PUC03.05. Smart Charging to minimize time of charge • PUC03.07. Grid management
Features to be tested	Visualization of summaries and charts with global information related to the month
Preconditions (optional)	1) The use has to be logged into the application. 2) One user in "TwinEV for drivers" application is making actions related to charge sessions 3) One user in "TwinEV for grid operators" application is setting restrictions to the charging points
Previous steps (optional)	
Dependencies (optional)	
Steps	1. Go to screen "Analysis" 2. Ensure that month selector is set to the current month. 3. Check the information

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Postconditions	• The table is updating in real time and including new information conform operations are done in the other applications
Acceptance criteria	Information is updated in real time
Suspension criteria (Optional)	The information is not updated in real time

Annex 2. Terms and conditions

Like for the rest of software oriented to final users in TwinERGY, before starting to use "TwinEV for drivers" application, it is needed to accept some terms of the service. In case of TwinEV, the terms of the service are the following ones:

Dear Pilot Users,

A big thank you for volunteering to participate in the TWINERGY "Pilot" phase and for your patience and support so far!

We are now ready to provide you the complete version of the TwinEV mobile application to officially start trying it out to support you managing your EV charging process.

We collect and process your personal data for the sole purpose of participating on TwinERGY project. Your data will be used solely by the persons or teams in ETRA I+D who require access to it to carry out their work and it will never, under any circumstances, be made available to third parties or transferred to third countries or international organisations. We can only process your personal data with your consent, and it will be retained only as long as you do not withdraw consent. You can exercise all your rights under current data protection regulations, including the right to access, correction, objection, erasure, portability and restriction. By accepting these terms, you acknowledge that you have been appropriately informed and that you consent to the processing of your personal data for the stated purpose.

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References

[1] ENTSO-E, Electric Vehicle Integration into Power Grids, ENTSO-E Position Paper, 2021.

[2] EMAAS CONSORTIUM, EMAAS Project Public Summary Reoirt, European Comission, Electric Mobility Europe, 2020.

[3] MEISTER Project, "MESITER Project," [Online]. Available: https://meisterproject.eu/.

[4] S. C. W. J. V. M., "D3.1 MEISTER Architecture," 2019.

[5] KeyCloack. [Online]. Available: https://www.keycloak.org/.

[6] Keycloak, "Server Administration Guide," [Online]. Available: https://www.keycloak.org/docs/latest/server_admin. [Accessed 2022].

[7] TwinERGY Project, "Deliverable 4.4 - System Architecture," 2021.

[8] ENTSOE, "ENTSOE - Transparency Platform," [Online]. Available: https://transparency.entsoe.eu/.

[9] Wikipedia, "International Electrotechnical Commission," [Online]. Available: https://en.wikipedia.org/wiki/International_Electrotechnical_Commission.

[10] ELlaadNL. [Online]. Available: https://www.elaad.nl/.

[11] E. Foundation. [Online]. Available: https://evroaming.org/.

[12] NATS. [Online]. Available: https://nats.io/.

[13] Docker, "Developers Love Docker. Business Trust It.," [Online]. Available: https://nats.io/.

[14] C.-C.-E. S. G. C. Group, "Smart Grid Reference Architecture," 2012.

[15] European Commission, "New Cost Efficient Business Models for Flexible Smart Grids," [Online]. Available: https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-energy/grids/nobel-grid.

[16] E. Commission, "Wide scale demonstration of Integrated Solutions and business models for European smartGRID," [Online]. Available: https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-energy/grids/wisegrid.

[17] TwinERGY Consortium, "TwinERGY - Innovation Action," 2020.

[18] https://www.dermengine.com, "Dermengine," [Online]. Available: https://www.dermengine.com . [Accessed June 2021].

[19] IES, "iSCAN Intelligent Control and Analysis," [Online]. Available: https://www.iesve.com/icl/iscan. [Accessed June 2021].

[20] S. C. W. J. Vivó M., "D3.1 MEISTER Architecture," 2019.

[21] T. M. M. A., "D4.2- Smart grid services design. H2020 Userchi project," 2021.

[22] U.-C. Project. [Online]. Available: https://www.userchi.eu/.

[23] USER-CHI Project, [Online]. Available: https://www.userchi.eu/.