Deliverable D5.1: Planning of Virtual and real-world Demonstration Actions

Primary Author	Nicolas Rößler, Max Faßbender, Eleonora Innocenti, Lorenzo Berzi
Lead Beneficiary	RWTH Aachen
Deliverable Type	R – Document, report
Dissemination Level	PU - Public
Due Date	31.12.2023 (M12)
Pages	81
Version	2.1[1]
Project Acronym	XL-Connect
Project Title	Large scale system approach for advanced charging solutions
Project Number	101056756
Project Coordinator	Virtual Vehicle Research GmbH (ViV) Alois Steiner (alois.steiner@v2c2.at)

[1] First digit: 0 for draft, 1 work package approved, 2 executive board members approved, 3 coordinators approved

Contributors

Name	Organisation
Sara Cardoso	E-REDES
Dario Giannelli	ABB
Silvio Scaletti	ABB
Nicolo Russo	ABB
Jagadish Babu Vemula	ABEE
Da Wang	ABEE
Sara Cardoso	E-REDES
Max Faßbender	RWTH
Nicolas Rößler	RWTH
Xinyuan Cao	RWTH
Lorenzo Berzi	UNIFI
Massimo Delogu	UNIFI
Eleonora Innocenti	UNIFI
Anna Eisner	Virtual Vehicle
Maria Kourkouli	FEV

Formal Reviewers

Name	Organisation
Alois Steiner	Virtual Vehicle
Thomas Schade	FEV
Job von Rango	FEV STS
Luca Pugi	UNIFI

Version Log

Version	Date	Author	Description
1.0	07/12/2023	RWTH, UNIFI (all partners with DEMO)	First version ready for review. Part “Belgium” TBD
1.1	19/12/2023	RWTH, UNIFI (all partners with DEMO)	ABEE, E-REDES part updated General review and detailing
2.0	21/12/2023	RWTH, UNIFI	Ready for final review (Prof. Pugi)
2.1	22/12/2023	RWTH, UNIFI	Reviewed version
2.2	19/04/2024	RWTH, UNIFI, ABB, ABEE	Reviewed version including amendment

Table of Contents

Abbreviations and Definitions

AC	Alternating current
BESS	Battery Energy Storage System
BMS	Battery Management System
BS	Basic Signaling
CAN	Controller Area Network
CCS	Combined Charging System
CharIN	Charging Interface Initiative e.V.
CP	Control Pilot
CPO	Charge Point Operator
CT/IOP	Conformance Test/InterOPerability
DC	Direct current
DSO	Distributed System Operator
EIM	External Identification Means (External payment)
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FC	Fast Charging
GIS	Geographic Information System
HLC	High Level Communication
HPC	High Power Charging
IC-CPD	In-Cable Control and Protection Device
IEC	International Electrotechnical Commission
IOP	InterOPerability
ISO	International Organization for Standardization
ITCC	Interoperability Testing and Certification Committee
LLC	Low Level Communication
MPPT	Maximum Power Point Tracking

OEM	Original Equipment Manufacturer, here automotive manufacturers
OCPP	Open Charge Point Protocol
PTDF	Power Transmission Distribution Factors
PHEV	Plug-in Hybrid Electric Vehicle
PLC	Power Line Communication
PWM	Pulse Width Modulation
REC	Renewable Energy Community
RFID	Radio-Frequency IDentification
SoA	State of the Art
SOC	State Of Charge
TSO	Transmission System Operator
VPP	Virtual Power Plant
V1G	Unidirectional charging
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home
V2B	Vehicle-to-Building
V2X	Vehicle-to-everything

List of figures

List of tables

Executive Summary

The overarching goal of the XL-Connect project is the optimization of the complete charging chain – from energy supply to the end consumer. One main optimization aspect being the charging process and the utilization of smart charging and bidirectional charging functionalities. In order to maximize the potential of these functionalities, the development of adequate charging strategies is necessary and shall be realized within the XL-Connect project.

These strategies shall be tested in several virtual and real-world demonstrations, within the work-package 5 of the XL-Connect project. The real-word demonstration provides the proof of feasibility of these strategies in a real context. Beside private demonstrations, that are more controllable regarding the access of users, public demonstrators will also be implemented in order to acquire realistic user-data and verify the technical feasibility of the EVSE and the algorithm with a wide range of EVs. In addition, virtual demonstrations will cover use-cases with a higher amount of EVs as well as more complex use-cases.

This deliverable provides an overview of the virtual and real-word demonstrations treated in this project. Therefore, the geographical and grid circumstances of each real-world demonstrator are shortly addressed. Afterwards, a list of possible KPIs is provided that enables the evaluation of the results of every demonstration based on suitable measures. Every virtual and real-world demonstration provides information about the specific implementation of their demonstrator and formulates their research questions. Finally, this deliverable provides an overview of the links between the virtual and real demonstrations and lists the possible risks of the real-world demonstrations.

Keywords: smart charging, V2G, V2B, energy communities, simulated use-cases, real-world use cases, demonstrations, demonstrator, OCPP 2.x, ISO 15118-20

1. Introduction

The impact of the introduction of large electric vehicles fleets in the existing energy infrastructure strongly depends on the strategies adopted to support their charging needs. A synthetic description of the large literature existing on the topic states that such impact can vary from a very severe scenario - the case of unregulated charging procedures - to tolerable impact - the case of appropriate adoption of mitigation action, such as controlled, smart or even bidirectional charging; under certain condition, if the vehicle is participating to a "system", its capability of energy storage and conversion can contribute to enable advanced management of Renewable Energy Sources, energy districts and others.

Many demonstrations of this type exist in terms of running systems, experimental-prototype systems, simulated systems, hybrid systems; the challenge is certainly no more on the potential of such systems or on the availability of proper technologies, but mainly on the proper implementation according to continuous evolving contexts, including:

- the limitations related to the regulation
- the economic sustainability of the initiatives
- the adoption of recent standards
- the acceptance of users or stakeholders in general

The demonstration actions of XL-Connect described here have the ambition to implement in real systems a few typical scenarios, in order to demonstrate in the partner context - here, and now - the applicability of the most recent technologies for charging power management.

Demonstration action will involve both real case studies - considering a certain group of EVSEs, vehicles and users - and virtual case studies, where the application of concepts which individually can work is simulated and up-scaled in order provide a forecast on the future sustainability.

This document also summarizes the actions planned by the partners to implement in their facilities the demonstration action: where, when, what, which objectives are targeted and how their achievement is planned. During the planning phase of the demonstration actions, XL-Connect participants also wanted to investigate which Key Performance Index can be adopted to describe the impact of their actions, and for this reason a thorough examination of literature has been performed to identify the recognized quantitative indicators describing the effect of vehicle-grid interaction. Adopting this approach, each demonstration is then associated with the KPIs which are mainly suitable to describe their impact.

2. Overview on Advanced Charging Technologies

2.1. EVSE Technologies

The following subchapters are dealing with the investigated requirements (derived from the questionnaire, cf.) for the various actors involved in charging. These actors are:

- the EV (incl. vehicle sizes, battery, and drivetrain characteristics)
- charge points (incl. position; charging characteristic / power, no. of charging connectors etc.)
- the smart charging providers (incl. energy management, pricing)
- the grid and energy providers (incl. required power, energy density for defined areas)
- the users (incl. accessibility, easy application).

2.2. Grid Service Priorities

From an EV point of view (considering the variety of various vehicle sizes and different kinds of operable vehicle types) the requirements analysis for different smart charging mechanisms can start with a SoA analysis about current standards for bidirectional charging. Their advantages and disadvantages in terms of power-quality and voltage problems for the grid as well as the impact on battery degradation associated with different bidirectional charging techniques (AC vs. DC) on EV-side will be determined and help to formulate updated requirements for advanced charging technologies on how EVs could contribute to grid stabilization, see Figure 1.

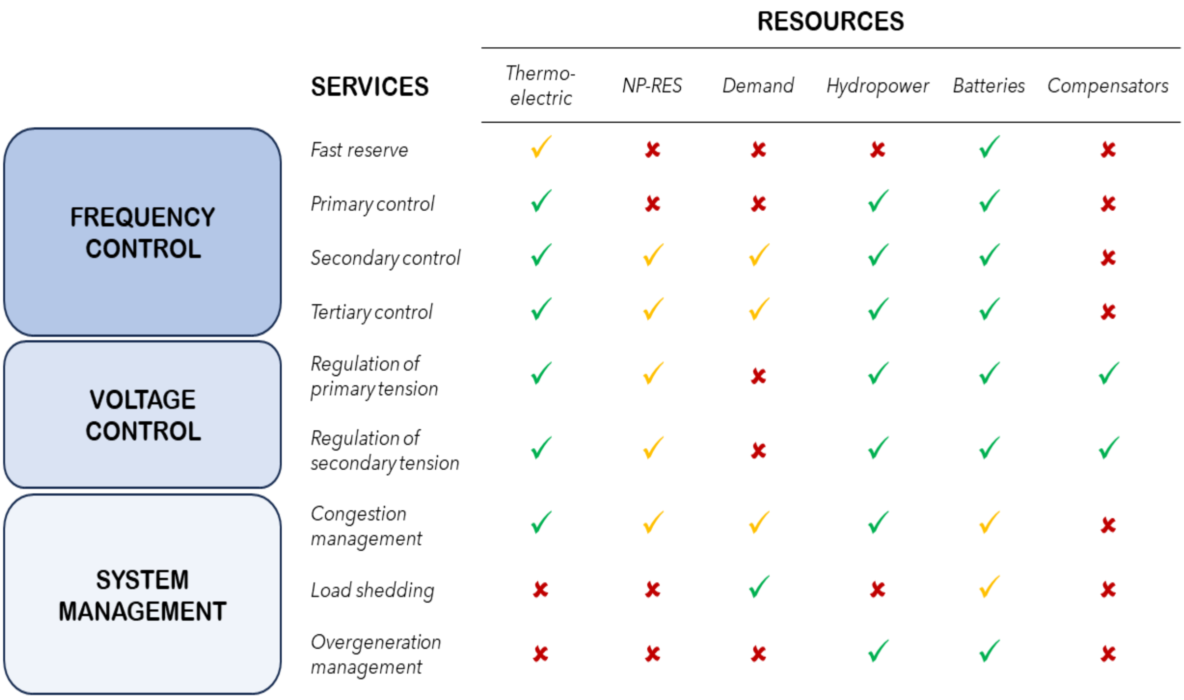

Figure 1 Exemplification of the ability of power resources to satisfy grid services.

2.2.1. Frequency Control

As already introduced in the deliverable 3.1 of this project, the nominal frequency of power systems in Europe is 50 Hz. The frequency is an important parameter to indicate the balance between supply and demand. An unbalance can directly be observed via an over- or under-frequency (cf. D3.1). To avoid damaging electrical components, the grid frequency shall be kept in a zone of +-10mHz around this nominal 50 Hz frequency [1].

Based on the spot prices on the day-ahead and the intraday market, TSOs (as well as DSOs in the future) predict grid congestions in advance and counteract these i.e. by demanding a change for power plant operating times. In addition, the frequency control is a control mechanism for reducing actual deviations between power supply and demand resulting from inaccurate predictions [2]. This frequency control is generally divided in the primary, secondary and tertiary control, which all have to fulfill different requirements on response time and duration of activation [2]–[4].

In addition to these control mechanisms, the inertia from the rotors of generators of conventional power plants reacts as an intrinsic mechanism to counteract frequency deviation [1]. With the increase in volatile renewable energy production and the decrease of conventional power plants, that use generators, these low-inertia situations are becoming more problematic [1]. A study from the university of cologne found out that the predicted remaining conventional power plants in the year 2040 are not sufficient to maintain the stability of the grid frequency [5]. Therefore, in the future another control mechanism is required as a fast control mechanism, called “fast reserve” in Figure 1.

Due to the fast response time of lithium-ion batteries, EVs with bidirectional capabilities are an option to provide this needed fast reserve [1], as depicted in Figure 1. This use-case is even predicted to become one of the most interesting for V2G applications [1].

In addition to this fast frequency reserve, bidirectional vehicles are also capable of providing primary, secondary and tertiary control. The only constraints being the number of connected vehicles to be able to provide the required power for the required time. With an increasing penetration of EVs, the available energy is predicted to increase significantly in the future.

In an exemplary study, the economic benefit of providing frequency control services with several 40 kWh EVs in Great Britain was analyzed [4]. The simulation for this analysis relies on real datasets from 7.163 Nissan Leafs. The results show a high spread of revenue, due to variations of standing time for every EV, with the average being 287 £/year/EV. The average energy exchange with the grid was 6.7 MWh/year/EV, which corresponds to 83 full equivalent charge cycles, considering that positive and negative power can be used for frequency control [1]–[4].

2.2.2. Energy Exchange

Beside the support of the grid in the form of frequency control, other use cases for V2G applications are possible, as shown in Figure 2 [1]. Whereas the frequency reserve requires high power for shorter amount of time, the use cases self-consumption increase, peak shaving and spot market trading require high energy saving capabilities for longer periods of time. These three use-cases are summarized under the term of energy exchange and their application with regards to V2G will be briefly introduced in the following:

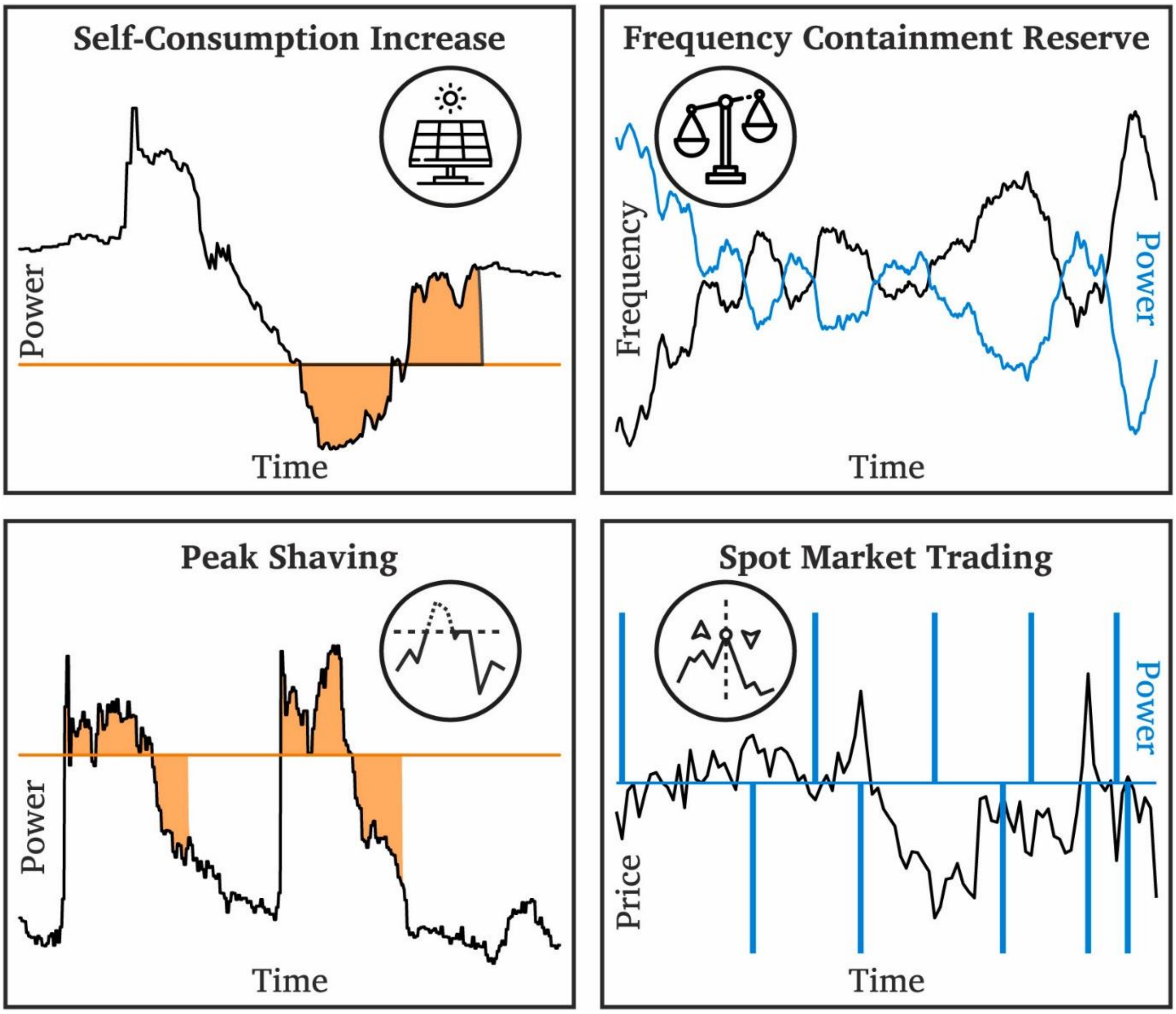

Figure 2 Schematic of the four V2G applications [1].

Spot market trading is a use-case focused on achieving profit or reducing charging costs enabled by varying electricity prices. The idea being to trade electricity on different energy markets, e.g. the day-ahead and intraday market [6]. The profitability of this use-case directly depends on the price spread of electricity. Most studies emphasize that under current market conditions, this use-case is not economically viable [6]. Although, due to the sinking costs of batteries, the increasing efficiency of the charging process and the increase of volatile renewable energies, which currently even leads to temporary negative energy prices, the spot market trading will become more relevant [1].

A disadvantage of the spot market trading are the additional costs that arise when selling or buying electricity in the form of different taxes and network fees. These costs need to be covered by the profit from spot market trading for it to be profitable. Instead of selling electricity back to the grid, an alternative is to redispatch the energy to applications in front of the metering device. In this case the battery of the EV can be used as an intermediate energy storage. The uses cases of peak-shaving and self-consumption increase fulfill these use-cases.

The self-consumption increase use case aims to store excesses in energy production in the battery of the vehicle instead of selling it to the grid and afterwards use this electricity instead of buying it. This is especially interesting for places with high renewable energy production and high retail electricity prices [1]. A disadvantage is that this use case is highly coupled to the mobility behavior of the user, as the vehicles need to be plugged-in in times of high PV generation [1].

The use-case of peak shaving on the other hand is applicable in times of high-power needs from a site. Since commercial customers are not only charged for their consumed energy but also for their peak power demand (e.g., average for a 15 minutes timeframe in Germany) [1]. To reduce this peak power, bidirectional EVs could provide the necessary energy in high demand times and could be recharge in low demand times. To effectively use this method, a precise prediction of the power peaks is necessary, to guarantee that enough vehicles are connected during these times [1]. The usage of self-consumption increases and peak shaving both lead to a smoother grid load.

2.3. Energy Management

2.3.1. On-Site Energy Management

Energy management systems have been studied broadly in the last years, focusing on on-site renewable energy production and consumption. Looking closely to EVSE technologies, charging solutions like V1G, are extensively assessed in real power plants along with RES, BESS or other prosumers. Those systems can be defined as “microgrid” or “standalone” system, one example of such a system being shown in Figure 3.

Figure 3 V2X Standalone System. Source [7].

The logic of management, in literature, is based on multi-objective optimization that consider the different features of the component involved in the system (e.g., PV power, current SOC of EVs) and objective targets (e.g., reduction of cost or peak shaving). The innovation of technology and the mass adoption of V2X solutions will introduce relevant challenges that energy management has to address:

- Implement new algorithms that consider the V2G charging schedule and the management scheme of the other power plant components.
- Potential financial benefits.
- Technology innovation for both EVs and grid side.
- Degradation of battery in V2G.
- Performance parameters that have to be investigated, in terms of KPI.

For a more detailed description of the topic, see deliverable 1.2 - chapter 1.

2.3.2. Virtual Power Plants and Energy Communities

As a renewable energy consumption solution, Virtual Power Plants (VPPs) have gained popularity in providing grid services (i.e., energy trading or cost optimization) by aggregating Distributed Energy Resources (DER), such as PV systems, BESS, charge points, buildings, and general demand-responsive devices [8].

Using the VPPs architecture, private citizens and companies can be organized in Renewable Energy Communities (REC) (– see schematic in Figure 4) in order to maximize the consumption of RES and provide economic and social benefits to the participants. In this case, the logic of energy management is not more based on local control or local targets but on “aggregators” that use shared communication protocol to impose a common energy strategy. Challenges and gaps are deeply explained in deliverable D1.2.

To better characterize the benefits of RECs is necessary to understand the current state of regulatory framework and the feasibility in XL-CONNECT demonstrator country. Following the Directive 2018/2001/EU (RED-II) [9] definition for *REC “is a legal entity that is based on open and voluntary participation, it is autonomous and controlled by shareholders or members located in the proximity of renewable energy plants belonging to the community itself. The members may be physical persons, companies or local authorities, the main objective of the REC is not to produce financial profits but to provide environmental, economic, and social benefits to its members or the local areas in which it operates.”*

Figure 4 Schematic representation of RECs. Source [10].

The European Commission has presented two directives to promote Renewable Energy Communities (see Figure 5):

- "Clean Energy Package" presented by the European Commission in 2016 [11].
- The Renewable Energy Directive (2018/2001/EU) (RED II) contains definitions, rights and obligations of RECs and requires EU member states to create frameworks for their development by June 30, 2021 [9].

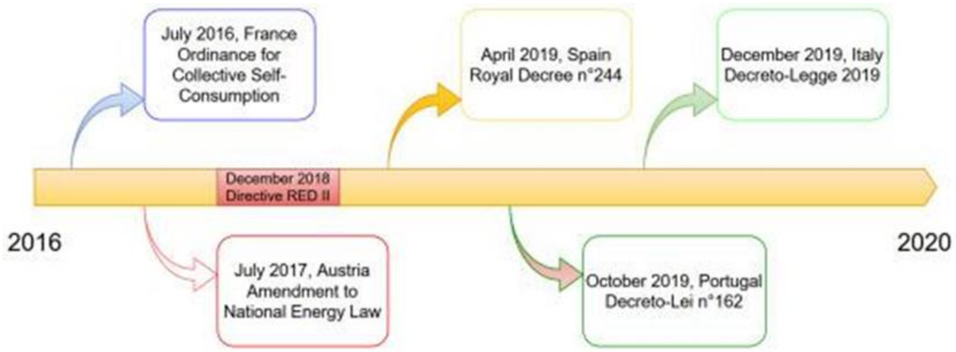

Figure 5 RECs Timeline. Source [12].

The RED II has provided a comprehensive list of key elements that a framework for RECs must include and has highlighted the necessity of the introduction of the concept of self-consumption of renewable energy and collective self-consumption to reduce the consumed energy from the grid [13]. During the last years, REC has been developed differently across Europe. The most advanced countries in this regard are Germany, Denmark, and the Netherlands. According [14] in 2019:

1. 1750 initiatives REC were active in Germany.
2. More than 700 in Denmark.
3. Almost 500 in the Netherlands.

The causes of those differences are mainly linked to national political framework and the feed-in tariff laws introduced in the late 1990s, which promoted the construction of renewable energy plants through incentives and subsidies and allowed small generators and municipalities to have an economic incentive to generate electricity from renewable sources [12].

An analysis of the REC current state is proposed in the paragraphs below, divided by XL-CONNECT partners' country; also challenges and opportunities are explained in detail.

2.3.2.1. Energy Communities – Germany

The extra-high-voltage grid in Germany is owned by four system operators (TSOs): TenneT, 50Hz, Amprion, and TransnetBW. These TSOs are responsible for the secure operation, maintenance and expansion of the infrastructure. The geographical breakdown is shown in Figure 6 [15]. For the Aachen-Region, the operator Amprion is responsible.

Figure 6 Geographical breakdown of Germany TSOs. Source [15].

According to the information provided [16], there is one extra-high voltage line (>350 KV AC) that leads to Aachen, which is then converted to two high voltage lines (+- 150 kV AC) that encircle Aachen in the north and east [17]. From these high voltage lines, several substations and distribution stations are used for conversion to the low voltage grid, as shown in the Figure 7 [18].

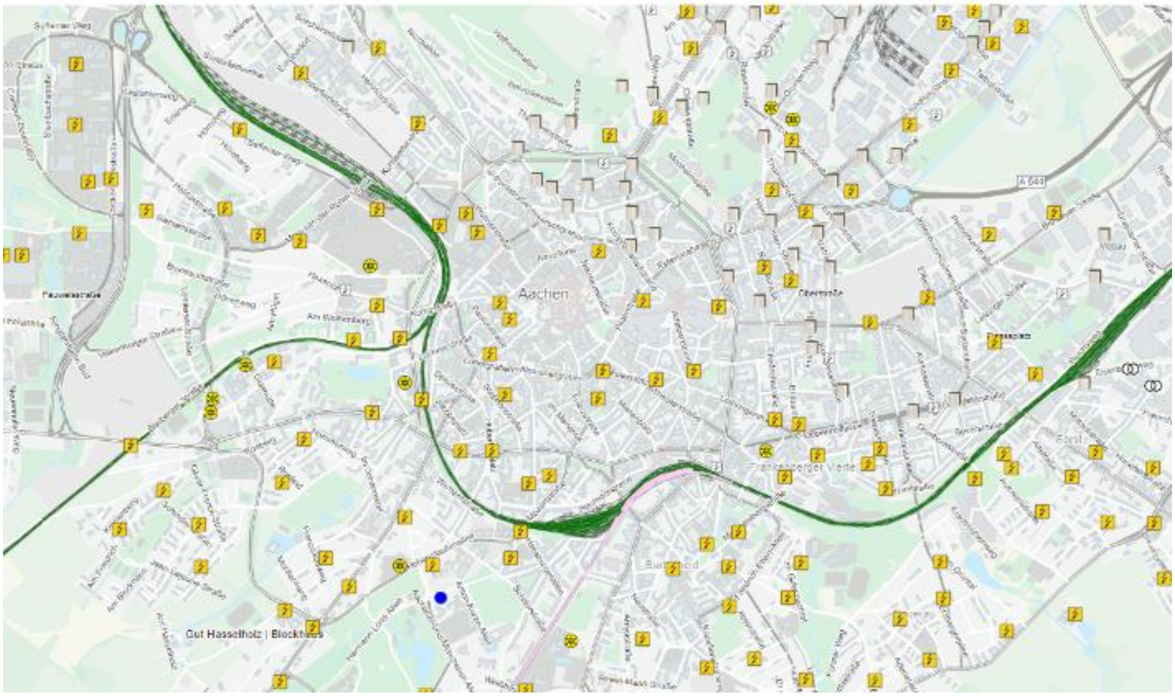

Figure 7 Substations and distribution stations in low voltage grid. Source [18].

In addition to the German grid, the Aachen region is connected to the Belgium grid via the ALEGrO (Aachen Liege Electricity Grid Overlay) commissioned by Amprion and the Belgian transmission system operator Elia. It has a transport capacity of about 1000 megawatts (MW). This capacity enables significant cross-border electricity flows between Germany and Belgium, supporting the integration of renewable energy sources and strengthening security of supply in the Aachen-Cologne region. The interconnector is approximately 90 kilometres long (on the German side, the length is 41 km), as shown inFigure 8 ALEGrO (Aachen Liege Electricity Grid Overlay) geographical area. Source [19]. Figure 8, and utilizes extra-high voltage direct current (HVDC) transmission technology. The converters establish a direct connection with the 380-kilovolt AC grid, as depicted in Figure 9. It was built as an underground cable, providing a more discrete and environmentally friendly solution compared to overhead lines [19].

Figure 8 ALEGrO (Aachen Liege Electricity Grid Overlay) geographical area. Source [19].

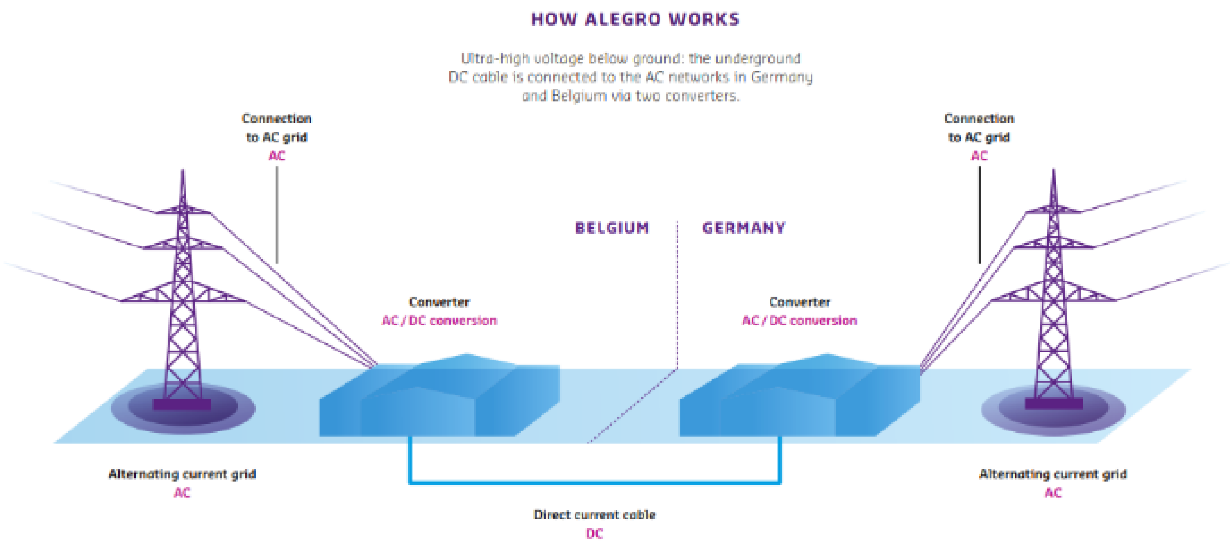

Figure 9 ALEGrO main components. Source [19].

For every household in Aachen, several electricity suppliers are available, while STAWAG is the basic supplier, and many households get their electricity from STAWAG [20]. Further information about the distribution networks from the high voltage into the medium and low voltage range and resulting "energy communities" could not be found. Also, most of these lines are not monitored. Since there is no real time supervision on these lines, there is no accurate information available on how the power is flowing within Aachen.

In regards to renewable energies, approximately 500.000 MWh of green production occur each year in Aachen. STAWAG, the provider of this green energy source, aims to complete a project of over 100 wind turbines with a production capacity of 100 MW by 2030. Currently, Aachen has 12 large solar energy plants and 35 grid- connected solar energy systems in addition to the home solar panels. There are also several wind parks around Aachen (Aachen, Münsterwald, Baesweiler, Gahrenberg) [21].

2.3.2.2. Energy Communities – Italy

During the last years, Italy has deeply promoted the installation of RES, focusing on the self-consumption of energies [22]. The RED II directive has been assimilated in Decree-Law 162/19 [23], defining the characteristics of RECs:

1. Establish a legal entity (i.e. association, cooperative) among the members of the community, whether they are natural persons, companies, or local public administrations.
2. Their members must be connected to the low voltage grid referring to the same medium-to-low voltage substation (could not act as a DSO).
3. The single RES installation owned by a REC could not exceed 200 kW nominal capacity.

4. REC participants preserve the right to choose their electricity seller and have the right to exit from the configuration at any time.
5. Specific incentive tariff that rewards self-consumption as an alternative to the other incentives currently in force.
6. Electrical energy is shared through the existing distribution network (virtual model).
7. The shared energy for instantaneous self-consumption is equal to the minimum between the energy fed into the network and the energy consumed by the REC members in 1 h.
8. RECs can participate in the electricity market, both as active users and distributors (manage their distribution network).

These constraints significantly limited the dimension and relevance of RECs and consequently the interest of stakeholders to invest in such projects. The legislation adopted in November 2021 (Legislative Decree no. 199/2021) relaxed those limits [13].

In particular, RECs are limited to the same electricity market zone and the incentives are granted to RECs where the members (producers and consumers) are connected to the same primary electrical substation (i.e., they can be connected to the medium voltage grid) and RES power plants are up to 1 MW [13].

Shared Energy Valorization	Jointly acting self-consumption	Renewable Energy Communities
ARERA contribute	10 €/MWh	8 €/MWh
MISE Incentive	100 €/MWh	110 €/MWh
Other Incentives	• Superbonus 110% (Italian incentives for infrastructure) • Installation tax discount 50% (December 31, 2020)	

Table 1. Economic Incentives in Italy. Source [24].

With the 727/2022/R/eel of December 2022 [24], the Italian authority AREA has passed the “Testo Integrato Autoconsumo Diffuso" (TIAD) that regulates the modalities for the valorization of the self-consumption energy previewed from Legislative Decree no. 199/2021 [9]: all the members of the community must be placed in a conventional area delimited by the primary electrical substation in which area self-consumed electricity is calculated and subject to economic benefits due to the avoided grid operating costs. Conventional areas (different colors in the Figure 10 and Figure 11) in which consumers/prosumers are placed [25], are shown In the web site of e-Distribuzione (Enel S.p.A. Italian national electric board).

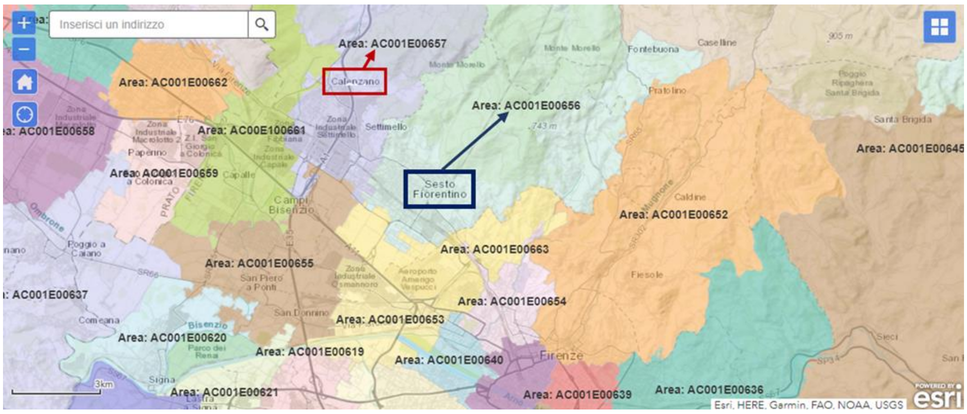

Figure 10 Conventional Areas for the UNIFI demonstrator are placed in the UNIFI campus (Sesto Fiorentino/Calenzano); renewable sources and other consumers must be placed in the specific area. Source [25].

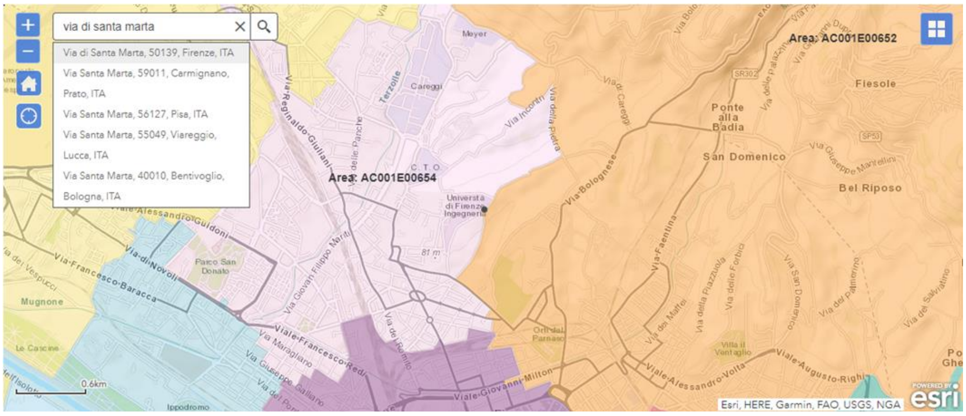

Figure 11 Example of conventional area for the University of Florence (Engineering Department). Source [25].

Despite the national policy, the RECs implementation in Italy varies from region to region in which regional laws promote different economic incentives and administrative approaches. The Italian organization Legambiente has written the 2022 Report on “Comunità Rinnovabili” [26], where 34 RECs in Italy are active and 41 in planning project. See Figure 12 for a qualitative representation and visit [27] for further details.

Figure 12 RECs in Italy. Legend: green leaf represents Renewable Energy Community, pink leaf represents Renewable and Social Energy Community, green and white symbol represents Collective self-consumption Community. Source Legambiente 2022.

2.3.2.2.1. REC and Electric Mobility: Italian example

An example of synergy between REC and electric mobility is the SOLISCA project, developed in the 2021 in Turano, Italy. See Figure 13 and Table 2.

Figure 13 Energy community of SOLISCA, Turano (LO), Italy. Source [28].

Groups	Characteristics
Site	Turano Lodigiano (Lodi), Italy
RES	PV peak power: 47 kWh
Energy Coverage	40% of energy demand
Prosumer	Municipality of Foiano di Turano Lodigiano, Sorgenia S.p.A.
Consumers	Citizens (23)
Founding	Private
Peculiarity	High social impact on the community of citizens

Table 2. SOLISCA main features.

The economic benefits of the project are divided between the municipality and low-income households. The PV is installed on the rooftop of municipal gym, canteen and Post office building [28]. The energy produced by the community feeds a charging station for electric cars (used by municipality and car-sharing services). The REC is using a digital platform provided by Sorgenia (Italian energy reseller) that allows to monitor the production of energy and the economic revenues of the community (at the end of the first years will be divided among members) [29]. In the last year, SOLISCA has produced almost 50 MWh of energy of which the 30% has been divided among members and generated an economic revenue of 15000 €. When SOLISCA was developed, a REC could not exceed 200 kW nominal capacity. With the main changes introduced by the Legislative Decree no. 199/2021, the community will be expanded up to 1 MW of capacity, including new consumers and new technologies (e.g., battery storage).

2.3.2.2.2. Challenges and Opportunities

Challenges and opportunities are briefly listed below, divided by main topics:

- *Fragmentation of the market* [30], that could cause additional complexity of electrical system control.
- *Energy Trilemma* [31], addressing energy security, energy equity and clean energy at the same time.
- *Points of connection (PoC) to the electric power grid,* RED-II directive refers only to the “proximity” of the members of the REC to renewable energy plants (e.g., members of the community connected to the same LV network downstream of an MV/LV substation), see Figure 14 [12]. For RECs two cases can be identified:
    a. If the distribution network belongs to the community, it is possible to install a single meter immediately downstream the substation and directly upstream the REC's network.

    b. In the case of REC in virtual models, it is not possible to associate a unique PoC to the community; in this case, the community connection points are as many as the participants in the community itself and the reading takes place through the energy balance considering all of them (single PoCs registered by the community manager).

- *Net-metering mechanisms*, there are model that quantify the compensation of energy produced or self-consumed [32]. An example is the "Scambio sul Posto Altrove" [33], a market framework used in Italy: SSPA is a simplified model dedicated to Public Administrations (PAs) that can feed the electricity into the network to consume it elsewhere without the coincidence of the point of production and consumption [12]. RECs are SPAA with citizens as participants and geographical proximity as limitation.

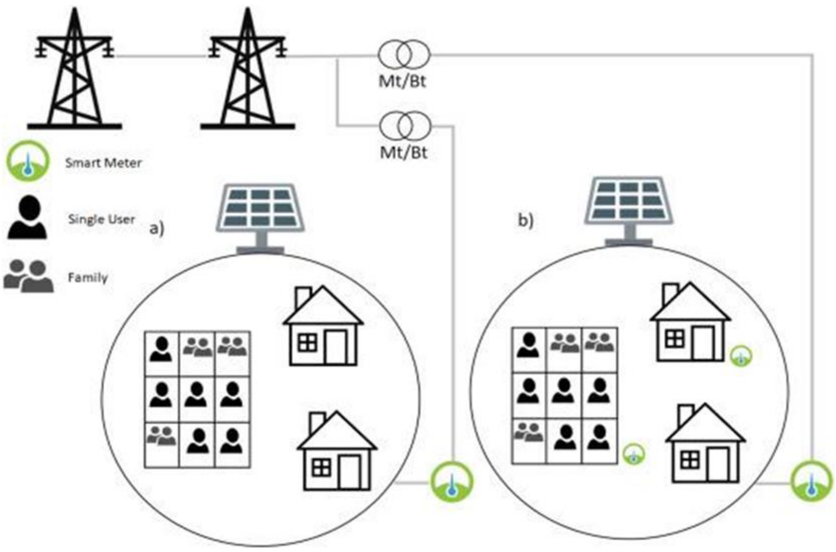

Figure 14 PoCs for RECs. Source [12].

- *Ancillary Services*, RCs and Demand response programs are structured in the same way (executed through the virtual aggregation of virtual units which makes their capacity available both for charging and discharging but with opposite purpose. Integrated DC programs, RCs could maximize self-consumption and provide ancillary services [34].
- *V2G service*, electric vehicles can be used as a distributed energy resource, providing electricity to the REC when needed to meet peak load demands that are not met by production within the community and then recharged during off-peak hours by absorbing excess generation [12], [35].

2.3.2.3. Energy Communities – Portugal

2.3.2.3.1. Portuguese Context

Portugal is among the countries in Europe that benefit from the best conditions for the use of photovoltaic solar energy, with irradiance values (kWh/m2) only seen in certain regions of Spain and in the extreme south of Sicily in Italy. Alentejo and Algarve are the regions in Portugal where the highest values of irradiance per square meter are registered, with over 2000 kWh/m2 per year.

Since January 1st, 2020, companies, municipalities, and individual consumers can organise themselves and create a renewable energy community in Portugal. The National Plan for Energy and Climate 2021-2030 (PNEC 2030) sets out the national targets for the use of renewable energy sources for Portugal until 2030. Although it does not provide specific targets for the implementation of renewable energy communities, the plan refers to the importance of energy communities for the achievement of national targets for the use of renewable energy sources and the reduction of greenhouse gas emissions, being relevant essentially for the specific targets for solar photovoltaic generation.

In Portugal, the legal regime applicable to renewable energy communities is defined by Decree-Law no. 162/2019 of 25th of October 2019 [36].

2.3.2.3.2. Real-life Examples in Portugal

Miranda do Douro Energy Community

- Production, consumption and sharing of energy between three buildings of Misericórdia de Miranda do Douro (headquarters, nursing home and long-term care unit).
- Active since: August 2021.
- Ownership structure: Benefit-sharing contract, where the initial investment was assured by Cleanwatts, a cleantech digital company.
- Cost Savings: A reduction in energy costs of at least 10% compared to the standard market price of electricity is expected.
- Production: Photovoltaic solar capacity installed on multiple roofs.

Coopérnico Energy Community Pilot-Project

- Tests how existing legislation and regulations work on the ground, take the learning needed to participate in improving the legal framework and technical tools, and to understand opportunities and barriers for citizens.
- Active since: November 2021.
- Cost Savings: Each family is expected to save around 145 euros per year.
- Production: Five 450Wp photovoltaic modules, with a total production capacity of 3307 kWh per year.

Community S [37]

- Creation of Energy Communities that bring together multiple buildings and homes to test energy sharing models between them.
- Promotion of community-wide initiatives to shift peak times of consumption to periods when electricity is cheaper or when there is more solar panel production capacity, showing the benefits and savings for the whole community.

- Implementation of energy management technologies in buildings and residences.
- Production: Photovoltaic (8 production units).
- Installation of distributed storage systems
- Implementation of a centralized software platform that will be in charge of acquiring, validating and storing the data collected for subsequent processing and application of decision support techniques based on neural networks and with a "learning capacity".
- Pilot-Communities (time period 2016-2018):
  - Penela (50 homes, city hall, library, auditorium, 2 schools, pavilion)
  - Alfândega da Fé (50 homes, city hall, cultural center, library, market)

Project "100 Aldeias" [38]–[40]

- Development of Energy Communities, in which diverse members are integrated, such as local entities, companies, local councils, IPSS, municipalities, and citizens, including economically vulnerable families, who benefit from an energy ecosystem, in which those who participate can have access to clean energy, with partial exemption from network access tariffs. Will impact 20,000 people in 100 small Portuguese villages, with an expected reduction of around 10% of their energy costs and an increase in their thermal comfort levels.
- The three RECs with closed investment represent an installed capacity of 269.5kW and, annually, will produce around 430 MWh of clean energy and avoid the emission of 77.4 tons of CO_2.
- In 2022:
  - Castelões.
    - Installed capacity of 86kW, will produce around 140MWh of clean energy per year. Will avoid the emission of 18.8 tons of CO_2 every year. This is equivalent to the CO_2 absorption of about 900 trees.
  - Soutelinho da Raia e Fornos.
  - Zambujal.
- The implementation of the Renewable Energy Communities in these three municipalities resulted in a reduction in the grid access tariff from 15.1% to 23.6%, which consequently reflected a reduction in the total cost of the bill depending on the tariff regime adopted.

Argacol – Industrial Community [41]

- An estimated energy cost reduction of 33%.
- Savings of 1488 Euros, after the initial 2 months.
- Installed power 630 kW
- Excess sold within the community at 10 Euros/MWh

Estádio do Dragão Community and F. C. Porto Olival Training Centre Community (not started)

In total, more than 2,000 solar panels will be applied with a combined capacity of around 1,170 kW which will allow the generation of more than 1,500 MWh per year. The use of renewable energy will allow FC Porto to reduce CO_2 emissions by 420 tons per year, the equivalent of planting almost 20,000 trees.

Greenvolt and Super Bock Group (not started) [42]

- Creation of six new Energy Communities in the Super Bock Group in the North and Centre of Portugal.
- Installation of about 20,000 solar panels in six units of the largest Portuguese soft drinks company. These panels will have a global installed capacity of around 11 MWp. With this solution, the Super Bock Group will be able to produce more than 16,000 MWh of clean energy annually, reducing its own energy needs and, at the same time, sharing the surplus with up to 5,900 companies and individuals in the surrounding communities, within a 4 km radius, who will be able to benefit from a reduction of up to 33% in the cost of energy.

Martifer Renewables (not started) [43]

Martifer Renewables and a group of companies from the Neiva Industrial Area signed a memorandum for the creation of a Renewable Energy Community, which will allow the companies to produce 47.6% of their annually needed energy, from a 100% renewable source. To this end, the construction of a 4.5 MW wind farm is envisaged.

Pilot project on Culatra Island [44], [45]

The initiative involves five Production Units for Individual Self-Consumption (UPAC), with 85 kWp, a further 30 kWp soon to be installed, an individual self-consumption with storage of 46 kWh, a solar boat with a 17.5 kWh battery and an energy management system, currently being developed at the University of the Algarve.

Pilot-project “Sonae Campus” – Maia [46], [47]

Inserted in the "Probono" Project

Pilot-project Agra do Amial – Porto (not started) [48], [49]

- The project will be implemented by December 2023.
- Creation of Porto's first renewable energy community to test models of micro-production of electricity for collective self-consumption.

3. Demonstrations

3.1. KPI Assessment: Demonstrations and Target

Within the XL-Connect project, different virtual and real-world demonstration actions will be implemented in order to optimize the charging solutions like V1G, V2G, V2X (defined in the WP 4.1).

The following demonstration actions will be performed:

- Real-world:
    - Sector coupling: Belgium (Brussels).
    - Generic communication structure/open standards: Germany (Aachen).
    - Public area/University campus of UNIFI: Italy (Florence).
    - DC Microgrid for large parking area: Italy (San Giovanni Valdarno).
    - Interoperability: Portugal (3 demo cities).
- Virtual:
    - Industrial site: Neuman Aluminium Use Case (Austria)
    - Scalable solutions for large parking areas
    - On-road parking in smart cities

It seems clear that Key Performance Indicators can be used as an instrument to evaluate the accomplishment of the project objectives and as the same time deals with the peculiarity of each Virtual and Real Demonstrator, highlighting the results obtained and variety of strategies adopted.

Main Questions:

1. What are the most used KPIs in literature? Can they be divided into categories? Can be identified a list of possible *XL-Connect KPIs*?
2. According to the Partners, what are the most interesting KPIs for each Virtual and Real Demonstrator?

Steps:

1. State of Art analysis of the KPIs used for smart charging solutions.
2. KPIs-Demonstrator Partners.

3.2. Literature Analysis on KPI

This State of Art analysis aims to summarize and identify a possible list of KPIs that can be applied to multidirectional charge and discharge processes.

Framework:

1. List of references that assess application in line with the project's scope (e.g. smart grid and smart charging, fast charging station and vehicle to grid / vehicle to X): 11 papers [50]–[60]
2. For each KPI the following attributes are specified:
    - Categories:
        - Environmental
        - Social
        - Technical
    - Brief definition
    - Unit
    - Literature source
    - Application (e.g. smart grid, V2G, smart charging solution)
    - Stakeholders involved, using three macro labels TSO (Transmission system operator that manage the general power grid), Consumers and Investors/aggregators.

In Table 3 all the KPIs used in different applications are listed. It can be noticed that different literature sources agree on the same KPIs for *smart grid application*: that's because the energy management of a smart grid is well established and largely evaluated by academic resources in the last decade. For example, *degree of self-supply, grid congestion, energy losses and interruption due to failure or maintenance* from a technical point of view, and *reduction of GHGs, capital expenses and operative expenses* for environmental and economic KPIs.

On the other hand, for *V2G*, a variety of different indexes are found, but only economical and technical KPIs. KPIs to be mentioned are: *Time availability of each vehicle entering in the parking, initial state of charge, charge time ratio and total load supplied by V2G, battery degradation cost* and so on. From an economic point of view: Heilmann et al. 2021 focus on general *revenue* using V2G for different applications, but they do not specify any detailed user interface or specific energy price to encourage users to join a V2G project. This aspect is very interesting and could be used for Demonstrators that implemented V2G.

Lastly KPIs reported in the European Project *Assured* on Fast and Smart Charging are reported, in order to evaluate specifically indexes on battery, charging point and vehicle.

Category		KPI	Definition	Unit	Source	Applic.	Stakeholders
Environmental		Reductions of GHG emissions	Reduction of GHG emissions	$tCO2_{eq}$/year	[51], [52]	Smart Grid	TSO/Consumers
		Carbon Dioxide Emission Reduction	Carbon Dioxide Emission Reduction	tCO2/year	[50]	Smart Grid	TSO/Consumers
		Air Quality Index	Average air quality	Index of PM10	[50]	Smart Grid	TSO/Consumers
		Primary Energy Demand and Consumption	Primary energy demand/consumption encompasses all the naturally available energy that is consumed in the supply chain of the used energy carriers	kWh/year	[50]	Smart Grid	TSO/Consumers
		Energy efficiency	Improvement of the energy efficiency of electric appliances	%	[44]	Smart Grid	TSO/Consumers/Investor
		Fossil fuel use	Reduction of the use of fossil fuels	T oil_{eq}/year	[51], [53]	Smart Grid	TSO/Consumers/Investor
		Noise Pollution	Noise pollution compared to previous condition	%	[50], [53]	Smart Grid	Consumers/Investor
Technical	Smart Grid	Energy losses	Reduction of energy losses in the distribution system	kWh/year	[51]–[53]	Smart Grid	TSO/Investor
		Peak-load	Curtailment of the peak power by load shift or load-shedding	% of peak power reduction	[51], [53]	Smart Grid	TSO/Consumers/Investor
		Share RES	Increase in the share of renewable energy in the generation of electricity	%	[51], [53]	Smart Grid	TSO
		On-site Energy Ratio	Relation between the annual energy supply from local renewable sources and the annual energy demand	%	[46]	Smart Grid	TSO
		Share of DER	Share of decentralized energy resource in the energy mix	%	[51], [53]	Smart Grid	TSO
		Energy use	Energy consumption reduction in different sectors	%	[51]	Smart Grid	TSO/Investor
		Maximum Hourly Surplus-Deficit	Maximum value of how bigger the hourly local RES supply is than the yearly demand	kWh	[53]	Smart Grid	TSO
		Reduced Energy Curtailment of RES/DES	Difference between energy curtailments before and after RES/DES integration	%	[53]	Smart Grid	TSO/Investor
		Grid Congestion	Grid sustainability to peaks	%	[53]	Smart Grid	TSO
		Electric vehicles integration	Increase of the number of electric vehicles in circulation over time	%	[51]	Smart Grid	TSO/Consumers/Investor
		Quality of energy supply	Improvement in quality of service for the consumers	%	[51]	Smart Grid	TSO/Consumers/Investor
		Accuracy of supply and demand prediction	Increase accuracy of the systems (reduction of the demand and/or supply forecast error)	RMSE(root mean square error)	[51], [53]	Smart Grid	TSO/Investor
		Energy storage development	Development and increase in the use of storage technology	%	[51]	Smart Grid	TSO/Investor
		Storage Energy Losses	Losses because of storage	%	[53]	Smart Grid	TSO/Consumers

		System Average Interruption Frequency Index (SAIFI)	Measure the average frequency of power supply interruptions	interruption/costumery	[51], [53]	Smart Grid	TSO/Consumers
		System Average Interruption Duration Index (SAIDI)	Measure the average cumulative duration of power-supply interruptions	minute/customer(year)	[51], [53]	Smart Grid	TSO/Consumers
		Customer Average Interruption Duration Index (CAIDI)	Measure the average cumulative duration of power-supply interruptions	minute/customer(interrupted)	[52]	Smart Grid	TSO/Consumers
		Flicker	Measure the rapid fluctuation in the voltage that cause change in brightness	%	[52]	Smart Grid	TSO/Consumers/Investor
		Voltage deviation	Difference between the actual voltage supplied to MV/LV users and the nominal value	%	[52], [53]	Smart Grid	TSO/Investor/Consumers
		Harmonic distortion	Harmonic distortion	%	[52], [53]	Smart Grid	TSO/Investor
		Battery Degradation rate	Rate at which the battery performance is deteriorating over a year/cycle	%	[53]	Smart Grid	TSO/Consumers/Investor
		Unbalance of three-phase voltage system	Difference in voltage of three phases	%	[53]	Smart Grid	TSO/Consumers
		Degree of self-supply (RES)	Percentage of self-generated energy not injected to the grid	%	[53]	Smart Grid	TSO/Consumers
		Frequency Control	Calculated the percentage of time that the average value of fundamental frequency measured over periods goes out of stated ranges	%	[53]	Smart Grid	TSO/Consumers
		Power demand for opportunity charging stations	Availability of energy for opportunity charging system	kW	[60]	Fast and Smart Charging	/
		Power demand for overnight charging stations	Availability of energy for overnight charging system	kW	[60]	Fast and Smart Charging	/
		Maintenance	Availability of the power grid considering the maintenance time, both scheduled and unscheduled	hour	[60]	Fast and Smart Charging	/
		Slow voltage variations	Stability of the power grid related to variations of slow voltage	%	[60]	Fast and Smart Charging	/
		Fast voltage variations	Stability of the power grid related to variations of fast voltage	%	[60]	Fast and Smart Charging	/
		Total Harmonic Distortion (THD)	Stability of the power grid related to the harmonic distortion	%	[60]	Fast and Smart Charging	/
	Battery	Nominal capacity	Performance of the battery associated to the nominal capacity	Ah	[60]	Fast and Smart Charging	/

		Storable energy	Performance of the battery associated to the energy that can be stored in a battery	kWh	[60]	Fast and Smart Charging	/
		Maximum charge current	Performance of the battery associated to the maximum sustainable charge current	A	[60]	Fast and Smart Charging	/
		Maximum continuous discharge charging	Performance of the battery associated to the maximum sustainable discharge current	A	[60]	Fast and Smart Charging	/
		Nominal battery voltage	Performance of the battery associated to the nominal battery voltage	V	[60]	Fast and Smart Charging	/
		Working voltage range	Performance of the battery associated to the difference between maximum and minimum voltage in working conditions	V	[60]	Fast and Smart Charging	/
		Charging current over 5 min	Performance of the battery associated to the maximum current that can be achieved during 5 min of opportunity charging	A	[60]	Fast and Smart Charging	/
		Charging power over 5 min	Performance of the battery associated to the maximum power that can be achieved during 5 min of opportunity charging	kW	[60]	Fast and Smart Charging	/
		Maximum charging capability	Performance of the battery associated to the maximum power that can be transferred in the battery during a charging	kW	[60]	Fast and Smart Charging	/
		SOC range (min/max)	Performance of the battery associated to the difference between maximum and minimum values of State of Charge	%	[60]	Fast and Smart Charging	/
		Range for operational temperature	Performance of the battery associated to the range temperature (for operability)	°C	[60]	Fast and Smart Charging	/
		Number of maximum full (80%) charge cycles	Performance of the battery associated to the number of fully charge cycles leading to an 80% rest capacity	n°	[60]	Fast and Smart Charging	/
		Expected calendar life	Performance of the battery associated to expected lifetime	years	[60]	Fast and Smart Charging	/
		Dimension of battery system enclosure	Performance of the battery associated to the battery system enclosure	mm	[60]	Fast and Smart Charging	/
		Vehicle battery capacity ratio	Ratio between vehicle battery capacity and fleet battery capacity	%	Assumed	V2G	/
		Battery system weight	Performance of the battery associated to the weight of the battery system	kg	[60]	Fast and Smart Charging	/
	Charging Infras	Interoperability level: Authentication media	Availability of the charging system related to acknowledgment of users	Qualitative	[60]	Fast and Smart Charging	/

		Interoperability level: Plug and socket compliancy	Availability of the charging system related to standardization of connections and standards	Qualitative	[60]	Fast and Smart Charging	/
		System features: Interconnection	Availability of the charging system related to the interoperability of the system	Qualitative	[60]	Fast and Smart Charging	/
		System features: Data exchanges	Availability of the charging system related to the use of data communication systems	Qualitative	[60]	Fast and Smart Charging	/
		Business & legal features: Roaming agreements between operators	Availability of the charging system related to agreements between operators responsible of payment and legal issues	Qualitative	[60]	Fast and Smart Charging	/
		Maintenance	Availability of the charging infrastructure considering the maintenance time, both scheduled and unscheduled	Hours	[60]	Fast and Smart Charging	/
		Current quality: Phase of voltage relative to current	Availability of the charging point related to the negative effects of reactive power	Degrees	[60]	Fast and Smart Charging	/
		Current quality: Total Harmonic Distortion (THD) of the current	Availability of the charging point related to harmonic currents	%	[60]	Fast and Smart Charging	/
		Current quality: Peak current	Availability of the charging point related to peak current	A	[60]	Fast and Smart Charging	/
		Number of charging points	Availability of charging points in the city	%	[60]	Fast and Smart Charging	/
		Number of charging stations	Availability of charging stations in the city	%	[60]	Fast and Smart Charging	/
	V2G	Load supplied by V2G	Percentage of the total load supplied by the EV through V2G	%	[54]	V2G	TSO/Investment
		Max power from the grid	Maximum value for the grid interconnection	kW	[54]	V2G	TSO/Investment
		Frequency Control	Reduction of voltage fluctuation using algorithm of V2G	%	[56]	V2G	TSO/Investment
		SoC limits	SoC limits used to control performance algorithm of V2G	%	[56]	V2G	TSO/Investment
		Peak load shaving	Peak load shaving achieved using V2G	%	[56]	V2G	TSO/Investment
		Load levelling	Load levelling percentage achieved using V2G	%	[56]	V2G	TSO/Investment
		Energy Trading	energy used in Energy Trading (cost reduction and price arbitrage)	kWh/day	[58]	V2G	TSO/Investment
		Time available	Arrival and stops time	Hours	[56]	V2G	TSO/Investment
		SoC initial	Arrival SoC level	%	[56]	V2G	TSO/Investment

		Capacity of charging station	Ideal capacity of charging station	kW	[56]	V2G	TSO/Investment
		Charge/Discharge efficiency	Charge/Discharge efficiency	η	[56]	V2G	TSO/Investment
		Power mean square error (MSE)	that is the MSE of the active power trend supplied by the parking compared to the one required by a given Ancillary service market	RMSE	[56]	V2G	TSO/Investment
		Energy ratio	the ratio between the energy supplied during the V2G operations energy required by the AS	kW	[56]	V2G	TSO/Investment
		Charge time ratio	% of complete charging time respect to all charging action	%	[56]	V2G	Investment/Consumers
Economic	Capital Expenditure	Vehicle	Capex related to the purchase of the vehicle (including the cost of the battery)	$	[60]	Fast and Smart Charging	/
		Battery	Capex related to the purchase of the battery	$	[60]	Fast and Smart Charging	/
		Infrastructure	Capex related to the purchase and installation of the recharging point	$	[60]	Fast and Smart Charging	/
		Opportunity charging system	Capex related to the purchase of the opportunity charging system	$	[60]	Fast and Smart Charging	/
		Depot charging system	Capex related to the purchase of the overnight charging system	$	[60]	Fast and Smart Charging	/
		Installation Cost	Capex related to the installation cost of the charging system	$	[60]	Fast and Smart Charging	/
		Smart Charging	Capex related to the purchase of the Smart charging hardware	$	[60]	Fast and Smart Charging	/
		Power Grid	Capex related to the purchase of the electricity	$	[60]	Fast and Smart Charging	/
		Isolation and grounding system (safety)	Capex due to the purchase of safety instruments and systems	$	[60]	Fast and Smart Charging	/
		ICT compliance	Capex due to the purchase of smart charging ICT system	$	[60]	Fast and Smart Charging	/
	Oper ating expe	Vehicle energy efficiency	Energy efficiency during the vehicle operation, influence the opex of the vehicle	$	[60]	Fast and Smart Charging	/

		Vehicle energy consumption	Opex related to the energy consumption of the vehicle	$	[60]	Fast and Smart Charging	/
		Electric vehicle downtime	Opex due to the downtime period of the vehicle	kWh	[60]	Fast and Smart Charging	/
		Energy cost	Opex due to the energy cost	$	[60]	Fast and Smart Charging	/
		Power grid	Opex related to the power grid operational activity	$	[60]	Fast and Smart Charging	/
		Electricity network losses	Opex due to electricity losses during electricity distribution	$	[60]	Fast and Smart Charging	/
		Infrastructure	Opex related to infrastructure operational activity	$	[60]	Fast and Smart Charging	/
		Electricity network losses	Opex due to losses in the distribution network	$	[60]	Fast and Smart Charging	/
		Maintenance vehicle	Opex related to the maintenance of the vehicle, both scheduled and unscheduled	$	[60]	Fast and Smart Charging	/
		Maintenance infrastructure	Opex related to the maintenance of the charging infrastructure, both scheduled and unscheduled	$	[60]	Fast and Smart Charging	/
		Maintenance Power Grid	Opex related to the maintenance of the power grid, both scheduled and unscheduled	$	[60]	Fast and Smart Charging	/
	End-Of-Life Costs	Dismantling vehicle	Dismantling cost of only vehicle	$	[60]	Fast and Smart Charging	/
		Dismantling battery	Dismantling cost of only battery	$	[60]	Fast and Smart Charging	/
		Dismantling infrastructure	Dismantling cost of only infrastructure	$	[60]	Fast and Smart Charging	/
		Selling of materials and components, or second life	Cost for giving a second life to vehicle's components during the end of life or for selling activities	$	[60]	Fast and Smart Charging	/
	Re ve nu	Vehicles	Revenues depending on the vehicle battery system	$	[60]	Fast and Smart Charging	/

		Number of passengers	Number of passengers is fundamental for the computing of the payload	$	[60]	Fast and Smart Charging	/
	Smart Grid	Energy imports	Reduction of energy imports	%	[51]	Smart Grid	TSO/Consumers/Investor
		Energy cost	Reduction of energy cost	%	[51]	Smart Grid	TSO/Consumers/Investor
		NPV	How much an investment worth through its lifetime, discounted to today's value	$	[52]	Smart Grid	Investor
		ROI	Return on investment	%	[50], [53]	Smart Grid	Investor
		Payback Time	Amount of time it takes to get back the originally investment	Year	[50], [52], [53]	Smart Grid	Investor
		Cost per consumer	Includes both operation and investment expenses	$	[52]	Smart Grid	Consumers
		IRR	Equal to the discount rate that makes NPV equal to zero	%	[52], [53]	Smart Grid	TSO/Investor
		Total capital cost per kW installed	Initial cost of investment depending on the size	$/kW	[53]	Smart Grid	Investor
	V2G	Average cost per kWh	Average cost of energy taking into that own generation is free	$/kWh	[54]	V2G	TSO/Consumer
		Revenue stored energy	New revenue source by selling/purchasing electric energy stored in EV batteries to the distributed system operator	$/day	[58]	V2G	Consumers/Investment
		Cheaper electricity market alternatives	V2G can provide cheaper electricity market alternatives	%	[58]	V2G	TSO
		Revenue in load control	Revenue achieved in load control application	$/day	[55]	V2G	TSO/Investment
		Revenue in energy trading	Revenue achieved in energy trading application	$/day	[55]	V2G	TSO/Investment
		Revenue in frequency control	Revenue achieved in frequency control application	$/day	[55]	V2G	TSO/Investment
		Battery degradation cost	Battery valuation due to the degradation	$ / %(SoH)	[55]	V2G	TSO/Investment
Social		Customers' satisfaction	Increase in consumers satisfaction with their energy supplier	Linkert scale	[51], [53]	Smart Grid	TSO/Consumers/Investor
		Consumers' participation	Increase in consumers participation in demand response management programmes	Linkert scale	[51], [52]	Smart Grid	TSO/Consumers/Investor
		Fraud detection	Improvement of fraud detection in the electric sector	Linkert scale	[51]	Smart Grid	Consumers
		Employment rate	Increase in the employment rate	%	[51]	Smart Grid	Consumers
		Evaluation of cost of electricity bills	Evaluation of price policies	Likert scale	[52]	Smart Grid	Consumers
		Evaluation of fault repair	Evaluation of fault repair in case of an emergency	Likert scale	[52]	Smart Grid	Consumers
		Degree of Landscape Impact	Aesthetic measure	Likert scale	[53]	Smart Grid	Consumers/Investor

Table 3. List of KPIs used for different applications.

3.2.1. KPI Weighting

In the Table 4, partners responsible for the virtual and real demonstration actions have indicated the main KPIs, extracted from previous table.

	KPIs																
	Social			Environmental		Economic					Technical						
DEMO Actions	Consumers' participation	Customers' satisfaction	User behaviour regarding parking & charging	Reductions of GHG emissions	Primary Energy Demand	Red. of Energy cost	Pay-back Time	ROI	Net pres. value	Revenue in energy trading	Energy losses	Share RES	Maximum Hourly Surplus-Deficit	Storage Energy Losses	Reduction of energy exchange with grid	System features: Data exchanges	Grid Congestion
Aachen (Germany)						•				•						•	•
San Giovanni Valdarno (Italy)	•			•		•					•	•	•	•			
Brussels (Belgium)	•			•		•						•			•		
Portugal (3 demo cities)	•	•	•	•		•					•	•	•		•	•	•
Florence (Italy)	•			•		•						•	•				
Neuman Aluminium Use Case (Austria)			•				•		•				•		•		
Scalable solutions for large parking areas			•			•				•							•
On-road parking in smart cities		•	•			•				•							•

Table 4. KPIs indicated by virtual and real demonstrator partners.

3.3. Relation between real-world Applications and Virtualization Potential

Starting from the development of a predictive digital twin from WP 4.1, a detailed definition of the demonstration action will be proposed in the following two paragraphs (2.4 – 2.5).

The scenario definition and advanced charging features are summarized below (from WP 4):

- Advanced charging features:
  - Charging topology
  - Charging speed level
  - Charging technology
  - Charging Type
  - Local generation / consumption/ storage
  - User behaviour
  - Expected parking time
  - Vehicle type
  - Revenue/ Cost saving opportunities
  - Number of vehicles
  - Grid topologies (charging point usually connected to)

- Scenario defined and relative sub-components:
  - *Energy community neighbourhood* and *Residential*
    - Battery model of EV
    - Stationary Battery model
    - PV plant
    - Parking data
    - House consumption
  - *Urban Street parking* and *Highway charging*
    - Battery model of EV
    - PV plant
    - Parking data
    - User behaviour model

    - Charging point model
  - *University campus*
    - Model of EV battery and stationary
    - Model of charging station
    - PV plant
    - Parking data
    - User behaviour model
    - Aggregator
  - *Industrial site*
    - Model of EV battery and stationary battery
    - Model of charging station
    - PV plant
    - Parking data
    - Consumption of industrial site
    - User behaviour model
  - *Company vehicle fleets*
    - Model of EV battery and stationary battery
    - Model of charging station
    - PV plant
    - Parking data
    - Consumption of industrial site
    - User behaviour model

Integrating the methodology and the concepts developed for the simulation environment in the real and virtual demonstration enables the partners to take full advantages of a digital architecture developed in other WPs. Using those tools, a scale up twins of demonstrator can be tested in the next tasks (e.g., 5.2 or 5.4) investigating the challenges and benefits for all the future stakeholders. In addition, an alignment between the KPI shown in the previous paragraph and the ones used for simulation scenario has been done in order to obtain the fullest comparability of results.

3.4. Virtual Demonstration Actions

3.4.1. Case Study Definition

3.4.1.1. Neuman Aluminium (Industrial Site)

In this virtual use case, the expansion of renewable energy power plants in combination with different storage possibilities including a vehicle-to-building concept to optimize the on-site energy management are investigated. The goal is to analyze the overall energy consumption of the company as well as the impacts of increasing renewable energy sources and their associated financial benefits.

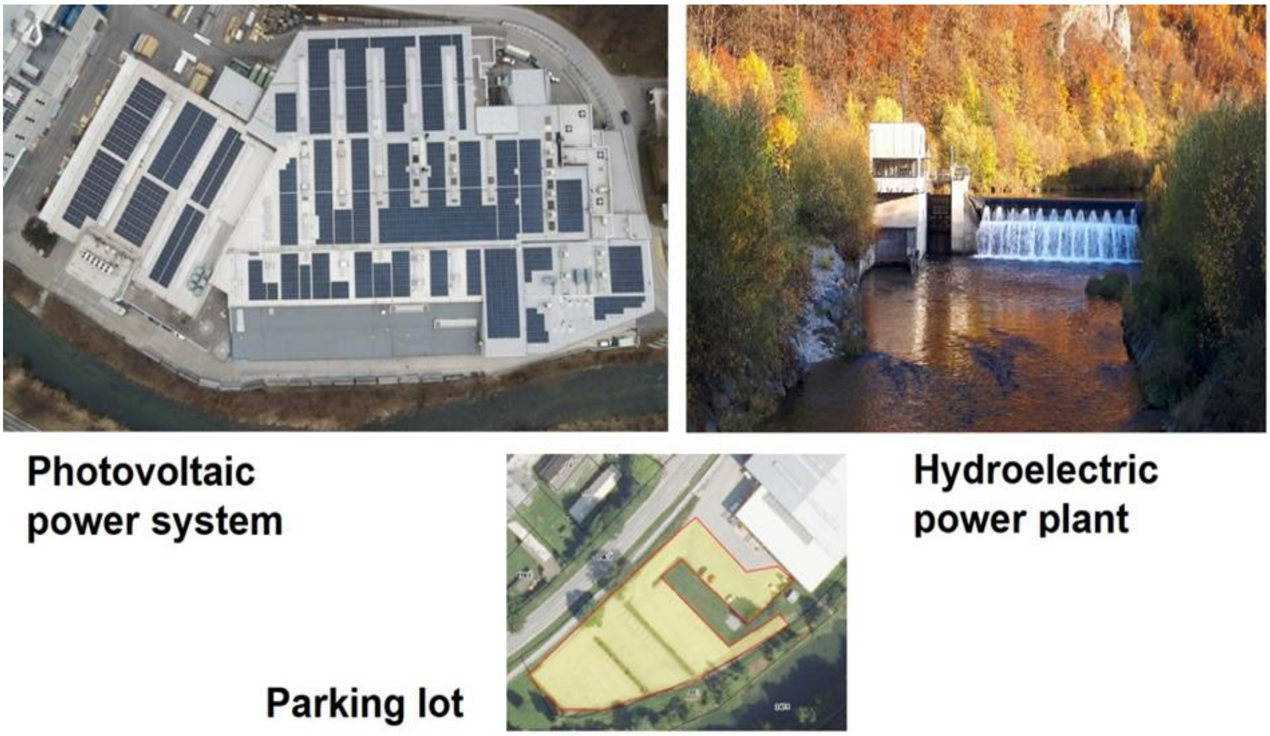

Figure 15 Neuman Aluminum - PV system, Hydro power plant and one of several parking lots.

In general, the company Neuman Aluminium, located in Lower Austria, produces aluminium parts and has an overall yearly energy demand of ~110,000 MWh according to their energy intensive production processes. Overall, the energy demand in 2022/23 of this use case can be divided in ~36% electricity demand and ~64% natural gas demand. According to this high energy demand, Neuman has employed two hydroelectric power plants with an overall size of 0.95 MWp and a photovoltaic (PV) system of size 100 kWp which was expanded to 1.1 MWp in June 2023. Currently, these power plants 4,100 MWh/year. As the production covers only 7.7 % to 10 % of the needed energy, Neuman wants to increase their renewable energy production by employing additional PV systems (up to 4 MWp). In addition, the virtual use case has an additional scenario where two wind turbines (overall 10 MWp) are employed. Therefore, three future scenarios for the virtual use case are elaborated:

	Status Quo	Scenario 1	Scenario 2	Scenario 3
Hydroelectric power plant	0.95 MWp	0.95 MWp	0.95 MWp	0.95 MWp
Photovoltaic system	1.1 MWp	1.3 MWp	4 MWp	4 MWp
Wind power station	-	-	-	10 MWp

Table 5. Scenario Overview - Neuman Aluminum Use Case.

To analyse these scenarios, a four-step approach is applied. In the first step, the energy production and consumption data of Neuman Aluminium will be assessed in order to determine the periods and amount of surplus of energy production for the different scenarios in the second step. With these findings, in the third step, a vehicle-to-building concept for a parking area with 300 vehicles for self-consumption optimization or peak shaving is discussed and conceptualised. Therefore, the parking situation at Neuman Aluminium will be analysed in order to determine the available energy storage capacity during the day, considering the different work shifts and fluctuations in the state of charge of the vehicles. When analysing this solution, it is also important to show under which conditions the employees would agree to (temporarily) discharge their vehicles. This is investigated by using survey data that were collected during the project and contain answers from all over Europe. In the fourth and last step, a battery storage is simulated as an alternative storage solution to the vehicle-to-building concept. A schematic overview of the working steps in the Neuman use case can be seen in Figure 16. For the analysis, the software RStudio and MATLAB are applied for data analysis and electric modelling.

Figure 16 Analysis Overview - Neuman Aluminum Use Case

3.4.1.2. Scalable Solutions for large Parking Areas – FEV Industrial Site

This virtual demonstration represents other similar industrial use cases with increasing power demand of EV charging by clean energy sources with important impact on the sustainability and the carbon emissions of the smart grid. FEV offers 26 unidirectional charging stations for their employers on the onsite parking place. The charging stations are operating with a maximum power of 22kW AC. At the moment, the charging is uncontrolled. Smart charging of EV can increase the synergy between photovoltaics (PV), and electricity usage, resulting in technological and economic advantages.

In order to achieve FEV's targets to reduce the energy taken from the grid by increasing the self-consumption and provide peak shaving, scalable smart charging algorithms will be developed, which will provide a centralized control. Reliable charging strategies will be designed. The scalability of this virtual demonstration can be represented in the input data, models, communication interfaces, and smart grid control algorithms.

The impact of smart charging & bidirectional charging which also takes PV energy, a heat pump and a stationary battery into account will be analysed in this virtual demonstration, as shown in Figure 17. The PV-plant will be installed on the roof of the building at the industrial site. The interaction between gird, PV and EVs will be explored based on the user behaviour. Also, the building consumption as well as the energy required to operate the test benches will be considered in this representative case study of sector coupling. The following figure shows the components that are managed by the charging management system.

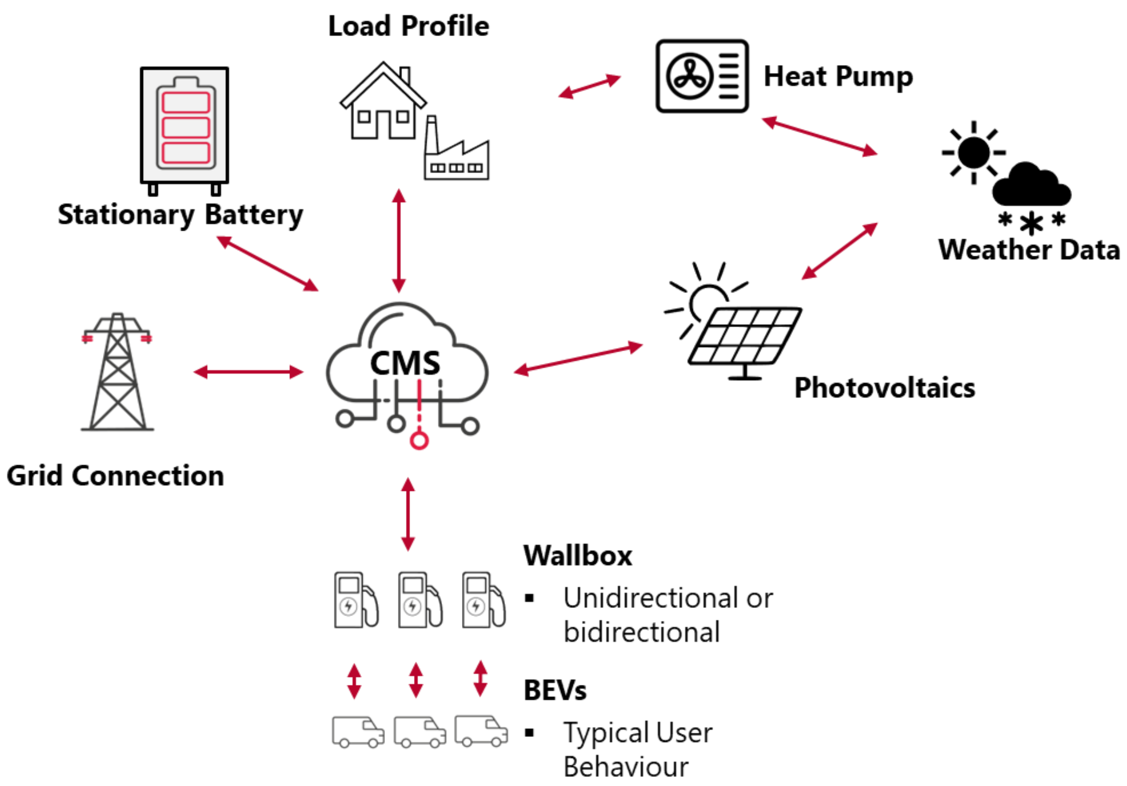

Figure 17 FEV charging management system architecture.

3.4.1.3. On-road Parking in Smart Cities

In this virtual demonstration, on-road parking with charging management strategy implemented in smart cities will be demonstrated. In general, there are three main steps included: data collection of on-road PCS (Public charging stations), modelling and strategy construction, virtual demonstration building up. On-road public charging stations data are being collected in Germany and Italy by RWTH and ESTRA respectively, as shown in Figure 18. Based on those collected data, system models are established.

In the end this virtual demonstration should be able to demonstrate the following points:

- Fulfil the user requirements (cost, time, location…)
- Bidirectional charging and smart charging implemented.
- Providing appropriate on-road charging solutions for different areas of the city
- Take battery degradation into consideration.

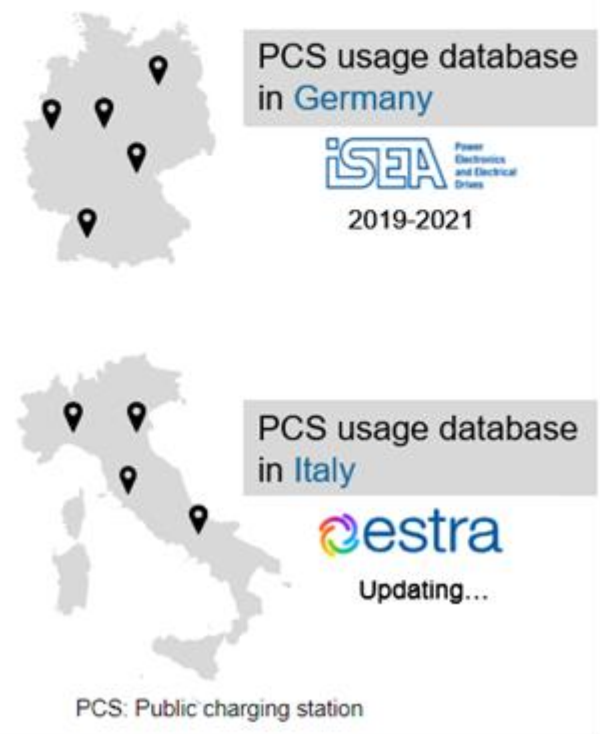

Figure 18 Public charging stations data collection in Germany and Italy.

3.4.2. Planning of the Neuman Demonstration

As explained above, the Neuman Aluminium virtual demonstration uses a four-step approach. In June 2023 the conceptualisation of the virtual use case as well as the data assessment started. As a first step, the energy demand of all facilities at Neuman will be assessed. This gives an overview on the energy needs of the industrial site. The data analysis serves as the basis for the following steps where vehicle-to-building as well as other storage possibilities are simulated and compared. Parallel to the data analysis, the conceptual design of the simulation model started in October 2023, which is expected to be finalised by end of 2024. The final step of the analysis, where different storage possibilities and investment scheme are analysed and compared, is planned to be finished by June 2025. Figure 19 shows the Gantt chart for the Neuman Aluminum use case.

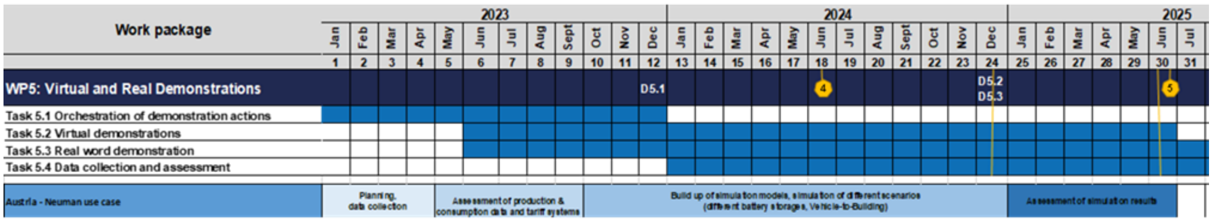

Figure 19 Gantt chart for Neuman Aluminum use case.

3.4.3. Planning of Scalable Solutions for large Parking Areas – FEV Industrial Site

The data including PV profile, industrial and office building load, charging data at parking area will be collected continuously from the end of 2023 to the end of 2024. Start from 2024 until mid of this year, first version of all the models needed for the virtual demonstration will be established. From July of 2024, a scalable smart charging algorithm will be development and simulated. From Feb. of 2025 to Jun. of 2025, simulation results will be analyzed and concluded, Figure 20.

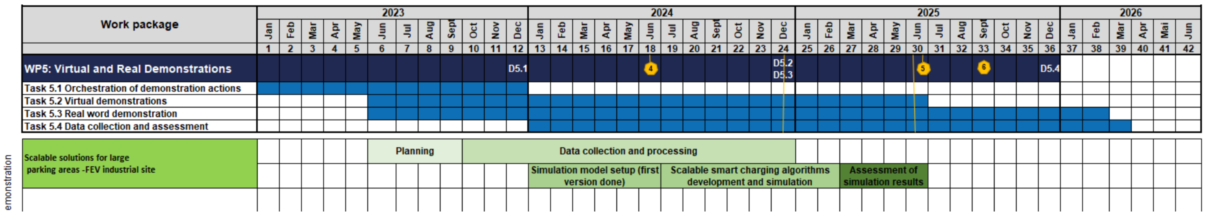

Figure 20 Gantt plan of Scalable solutions for large parking areas.

3.4.4. Planning of on-road Parking in Smart Cities

In 2023 on-street public charging data has been collected in Italy and Germany, these data will help to build up this on-road parking in smart cities virtual demonstration. The next step is to build up the sub models and smart city simulation scenarios. During 2024, Co-simulation will be done considering the user satisfaction. From March to June of 2025, simulation results of this smart cities virtual demonstration will be analyzed and reported, see Figure 21.

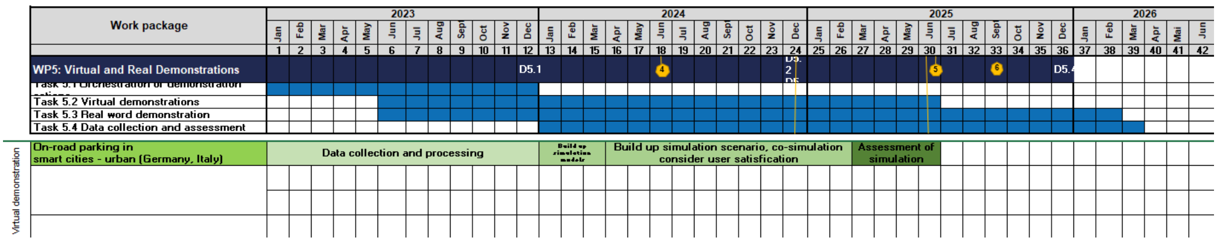

Figure 21 Gantt plan of on-road parking in smart cities.

3.4.5. Expected Results

Neuman Aluminium (Industrial Site)

The following research questions are addressed in the Neumal Alumunium use case:

1. From which energy surplus does a battery storage pay off and how large does it have to be?
2. From what range of price volatility (spot market) does a battery storage pay off and how large does it have to be?
3. Can a parking lot with 300 cars (electric vehicles) and a vehicle-to-building concept be an alternative solution to a battery storage?
4. What is the optimal solution for future investments (further increase of PV production or battery storage)?
5. Is an integration of an emergency power solution feasible (island-capable battery solution with base load 1 MW)?

From the analysis it is expected that especially in scenario 3, when wind power plant with 10 MWp is included, the generated energy surplus has significant impact on the energy usage of Neuman Aluminium. Especially in this scenario it is expected that storage solutions become crucial for an efficient energy management. In addition, the impact of energy flexibilization is expected to generate cost savings especially when energy prices are volatile.

Scalable Solutions for large Parking Areas – FEV Industrial Site

- If it's possible to reduce the energy taken from the grid by increasing the self-consumption and provide peak shaving on industrial site.
- If it is able to satisfy FEV EV users demands while providing V2G service?
- Quantify the benefits of V2G considering various constraints like grid connection or charging power and user demands.
- Based on the available industrial site consumption data, establishing one scalable system model can be used to analyse lage industrial site use cases.

On-road Parking in Smart Cities

- Verify the possibility of providing incentives to public on-street charging stations.
- How these incentives will influence the user's behaviour.
- Check if the EVs connected to public charging stations in a smart city are able to provide the V2G services?

3.5. Real World Demonstration Actions

3.5.1. Aachen Demonstration

3.5.1.1. General Introduction

The Location of the Aachen demonstration is at the premises of STAWAG, a parent company of Regionetz, at the Lombardenstraße 12-22 in Aachen. Three EVSEs will be set up at different locations in the parking area. One EVSE will be installed within the parking garage (1), the two other EVSE will be installed at the "Open-Air" location (2). The two locations are indicated in Figure . All three EVSE are bidirectional DC-Charging CCS-2 Stations with a maximum power of 11kW and a maximum voltage of 500V_{DC}. The access to the location is restricted and therefore no public user is allowed to charge there. The exact location of the EVSEs is shown in the next Figure.

Location	Parking	Open-Air
# of EVSEs	1	2
Power	11kW	11kW
Voltage	500 V_{DC}	500 V_{DC}

Figure 22 General information about the Aachen demonstrator location.

In order to guarantee that we are able to demonstrate bidirectional charging, three EVs are ordered for the Aachen demonstration. The vehicles are battery electric ID.4 from Volkswagen with a capacity of 77kWh. The vehicles are due to arrive at the end of 2023. In a first step, the EVs shall primarily be used by involved actors in the demonstration and they shall be charged at the project-EVSEs mentioned in the last paragraph. This approach is necessary to commission the bidirectional functionality of the EVs in combination with the EVSEs and the local controller. In a later stage of the project, the EVs and the EVSEs shall also be used by personal of Regionetz, that are uninvolved in the XL-Connect project, in order to create realistic driving & charging data for our use-case. E.g. the vehicles could be booked by specialists from Regionetz for their daily journeys to grid points around the Aachen city and the EVSEs could be used to charge personal EVs of Regionetz employees.

3.5.1.2. System Description

Beside this “real” use-case several other use-cases shall be demonstrated. E.g. the effects of highly fluctuating electricity prices or a high grid utilization shall be demonstrated. To guarantee the occurrence of the needed circumstances for these use-cases, we plan on operating the demonstrator in a simulated environment. To create this environment, it is essential to have the option of putting fictitious values to the controller and not relying on the real available values. To introduce these use cases, the setup of the local controller depicted in Figure 23 will be described in the following section.

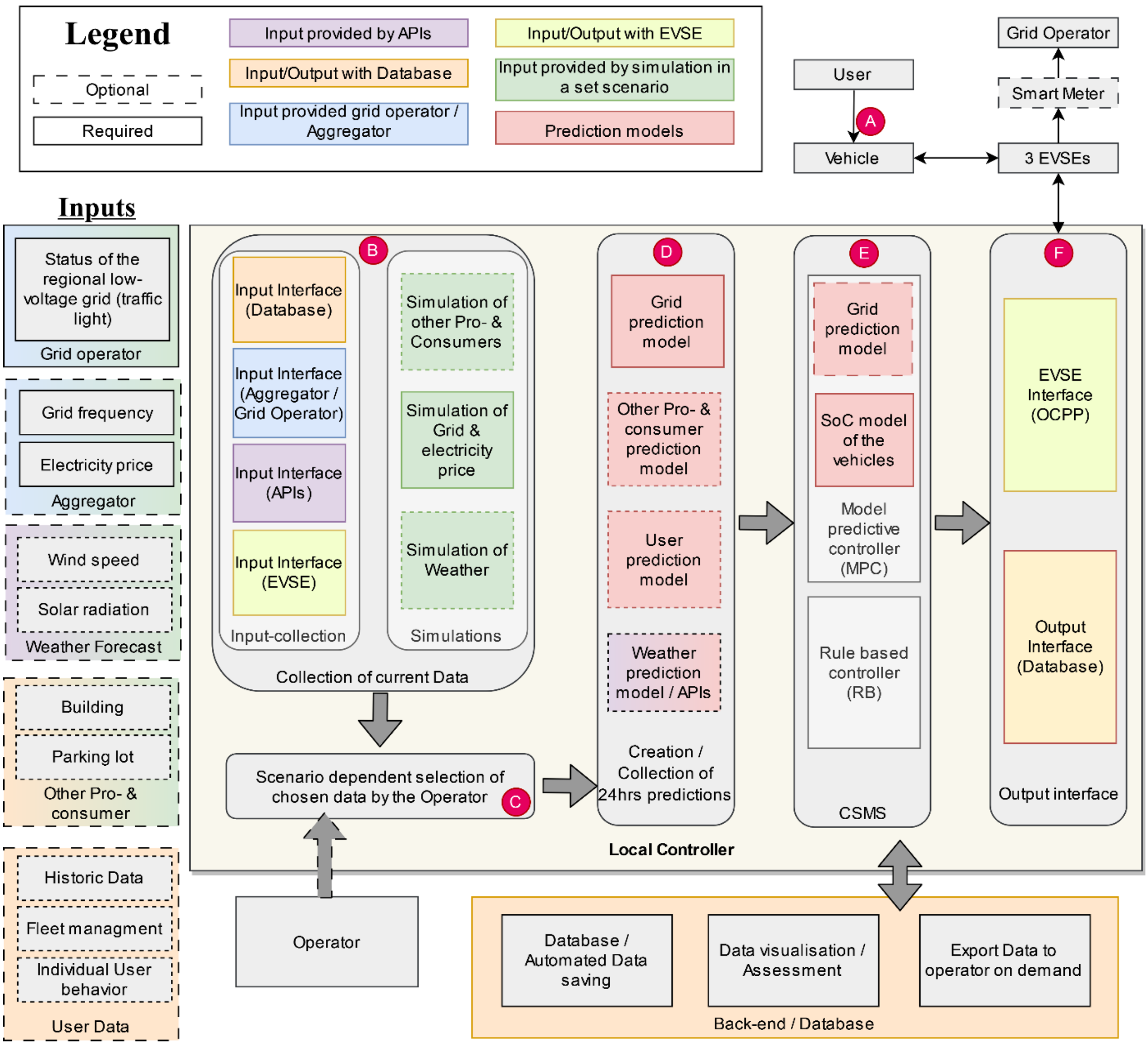

Figure 23 Layout of the Aachen demonstration with focus on the data transfer around the local controller.

The core part of this setup is the local controller. It will be implemented on a real hardware and establishes the communication between the EVSE, the back end and the grid operator. The goal of the local controller is the optimization of the charging process of all connected EVs while respecting all hard constraints like grid capacity and possible charging power. The result of the optimization will be a trade-off between the user satisfaction, the power demand at the location and the maximal use of renewable energies. For the user satisfaction several parameters can be considered, the two that will be considered for the demonstration are the discrepancy between the expected and real SoC of the vehicle at the departure time and the total price of the charging process. The individual steps of the controller will be described shortly in the following, according to the steps A-F in Figure 23:

Step A – User Arrival and plugging the EV:
The User plugs in the vehicle and the communication with the EVSE begins based on the ISO 15118-20. As specified in the norm, the following information for bidirectional charging need to be exchanged:

- “DepartureTime”
- “EVEnergyRequest” (Minimum, Target & Maximum)

During the charging process, the following data is exchanged as well: Current & maximum energy of the vehicle, (dis-)charging power, maximum charging & discharging power of the vehicle.

The possibilities to input these values are provided by the EV manufacturer, either by the vehicle display or an app. Via the same interface, the user can check the SoC of his vehicle and revoke the permission to use his vehicle for bidirectional charging, if needed. All communications with the EV user shall pass through the EVSE, which communicates with the local controller via OCPP 2.0.1, or with an update to OCPP 2.1 as soon as it will be available for the EVSE.

Step B – Information collection by the local controller:

In this step all necessary information for the optimization, provided by different sources, are collected by the local controller, the mentioned colors are referring to Figure 24:

- EVSE (yellow): As described before, the user transmits the information regarding his desired charging process to the local controller via the EVSE.
- Grid operator (blue): The grid operator will provide the current status of the regional low-voltage grid. This status will be based on a traffic light system, depicted in Figure 24 [61]: “Green” describing a stable grid, where the power exchange with the grid is only limited by the access point, “Orange” describing a heavily loaded grid, where users shall be incentivized to charge or discharge

their vehicle, “Red” describing an imminent grid overload, where all users shall charge/discharge as much as possible to counteract the grid overload.

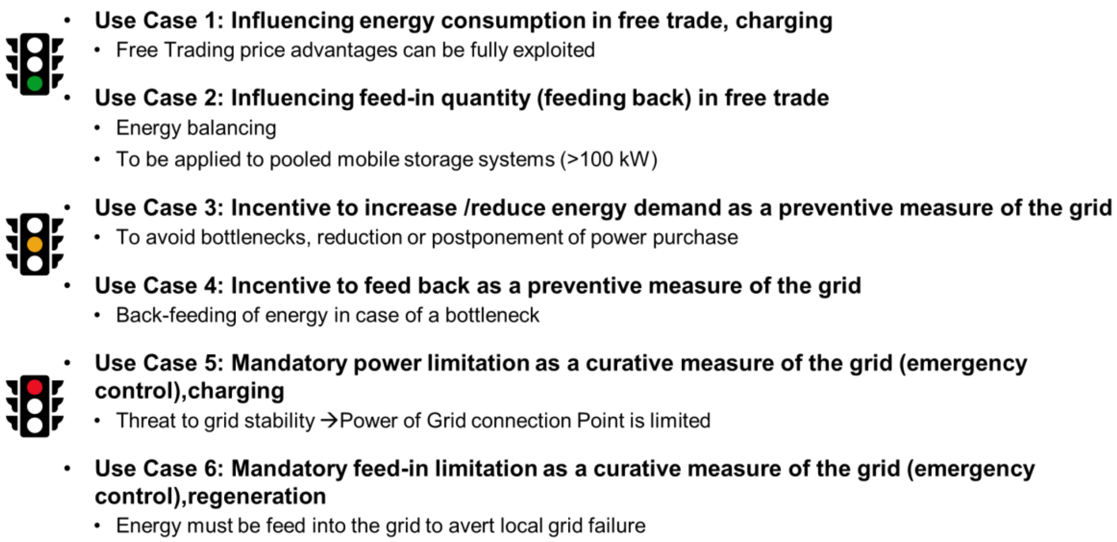

Figure 24 Status of the actual grid based on the traffic light system from TÜV Rheinland and IIT. Source [61].

- Aggregator (blue): The aggregator shall provide the information of electricity price and grid frequency. In contrast to the other inputs, the electricity price will already be provided for the next 24hrs as a fixed input and therefore doesn’t need to be predicted in step D. It is still unclear if an actual aggregator can be used within the demonstration, another option is therefore to receive this input as well from the grid operator.

- Application Programming Interface (API - violet): Although no renewable energy source is available at the location, the wind speed and solar radiation shall be requested by the local controller. This is done to predict the renewable energy production in the surroundings and use this information for the grid modelling. This input is optional and will therefore be implemented in a later stage of the demonstration.

- Database (orange): The data provided from the database includes user data as well as power data from other pro- & consumers. The power data from other pro- & consumers includes the total power consumption of the parking lot or the building or the whole side. The user data shall be implemented in a later stage of the project. Here different approaches shall be analysed. The historic approach is averaging the arrival and departure time of the vehicles on different days and the needed charging power. This is a first approach for optimising the charging schedule of vehicles that are expected to be plugged in later. Another approach is the analysis of patterns from specific vehicles instead of averaging the demanded power. A final approach that shall be analysed is the inclusion of the vehicles into a booking tool, so that the charging times for every vehicle can be predicted with highest accuracy. These approaches shall be tested separately and compared against each other.

Step C – Scenario Selection by the operator:

To ensure the correct behaviour of the local controller in cases of grid congestion it is important to test these conditions. However, the grid capacity and the grid connection at the location of the demonstrator are such, that grid congestion will not occur frequently with the current EV penetration. For this reason, the local controller allows the use of simulated data inputs as a replacement for some of the real inputs listed above. This includes the status of the grid, the electricity price, the power of pro- & consumers and the weather. The simulated values will be provided by simplified simulation models running on the local controller (provided by WP4).

In normal operation mode, the demonstrator will run based on the non-simulated values received by the input interfaces. When desired, the operator can start a scenario in which some of the simulated values will be taken as an input. Some scenarios are shortly explained in the following:

- Grid congestion: The current grid status and electricity price will be provided by the simulation. This allows to analyze the behavior of the local controller, when the grid provider requests the vehicles to discharge with maximum power e.g. The 6 traffic light phases used as current grid status are described in Figure 24.
- Renewable energy scenarios / Fluctuating powers: Different scenarios with strongly varying power consumers and sources shall be implemented to analyze the reaction of the optimizer.

Step D – 24hrs prediction:

The optimizer is a model predictive controller (MPC), which needs predictions of future states to optimizes the charging power. Some of these future states are dependent on the decisions of the model predictive controller, e.g., the future SoC of the vehicles depend on the charging power provided by the controller. The detailed behavior of this controller will be addressed in Step E.

Most predictions needed by the MPC are independent of its actions, like the weather, the arrival and departure time of users or the power consumptions by the building. Based on the current data received via the input interface by the different sources, 24hrs predictions are built for these inputs. These predictions need to be generated every time the MPC shall generate a new optimal charging power.

The last prediction model shall predict the status of the grid for the next 24hrs. This is an input that could theoretically be influenced by the charging power of the EVSE. As already mentioned, we don’t expect the grid to be overloaded at our grid connection. In this regard the grid prediction model shall be used to create predictions, used as a constraint for the MPC during optimization rather than a variable that can be improved by the MPC.

Step E – Charging Station Management System:

As described earlier the optimizer is a model predictive controller that will optimize the charging power of every EVSE based on the provided inputs. The optimizer will be executed with a constant frequency, in the range of 2-5mins. In addition to the optimization progress a rule-based controller is implemented to react fast to changing power limits of the vehicles or a changing grid status. This rule-based controller takes over the controlling of the EVSE charging power as long as it takes the optimizer to come up with a new solution for the changed inputs.

Step F – Output interfaces:

After the optimization, the calculated values shall be transmitted to the EVSEs. In a first approach one EVSE will be connected via cable to ensure a stable communication. In a later step the EVSEs shall communicate with the controller via the local secured WiFi. As mentioned, the communication will be done via the OCPP protocol.

Another output interface will be implemented to communicate with the back-end. According to WP5.4, the database shall collect the data of the demonstrator. In addition to the global output of the controller, every intermediate step shall be transmitted to the database.

3.5.1.3. Research Questions

Based on the demonstrator the following research questions will be investigated:

- Are the new open communication protocols ISO 15118-20 (EV-EVSE) and OCPP 2.0.1/2.1 (EVSE-local controller) working as intended / useable for all use-cases?
- Can the bidirectional EVSE be used to help with an impending grid congestion or even counteract a grid congestion?
- What renumeration for users is possible for supporting the grid when requested?
- What is the best trade-off between the user satisfaction, the power demand at the location and the maximal use of renewable energies?
- What is the best trade-off for users between satisfaction of the demanded energy and the charging price?
- What prediction accuracy of user behaviour is needed for an overall improved charging process?

3.5.2. University of Florence Demonstration

The UNIFI demonstrator is one of the very first coordinated energy management initiatives like an energy community created in public places on Italian and European territory, with the aim of supplying energy to charging stations on public land. Its main functions are:

1. Spread culture and knowledge on energy management for electric vehicles starting from structured academic and staff undergoing training.
2. Support the transition to electric vehicles by providing energy on non-profit terms for the supplier.
3. Impact on the territory by installing charging points directly on public land.
4. Allow the University of Florence to accumulate data regarding the optimal management of its offices in order to eventually expand the control logic (e.g., over 40 main university offices in the Tuscan territory).

3.5.2.1. System Description

The system consists of two main units which are located at the premises of the University of Florence in the area of the Municipality of Calenzano. The geographical areas identified make it possible to obtain suitability for the formation of Energy Communities in accordance with the provisions of ARERA resolution 727/2022/R/eel. Depending on the implementation methods, according to TIAD it is expected that in the first instance it could be an "individual remote self-consumer of renewable energy" or "remote active customer who uses the distribution network".

Specifically, the identification of the conventional area relating to the same primary substation was possible thanks to the digital maps made available by ENEL in 2023.

The main specifications are:

- MOVING LAB. The first unit is in Via Vittorio Emanuele 32, in the DIEF laboratory spaces. These spaces are accessible only by members of the University of Florence. The basic specifications of the unit include:
    a. A one-way AC charging point, with an indicative power of 22kW.
    b. Charging shelter based on a mobile-temporary structure that houses a photovoltaic system of at least 15 m2 with an expected nominal power of approximately 3.5 kW.
    c. Control system for communication, monitoring and remote control.
    d. Inverter storage system based on batteries with capacity between 5-10 kWh.
    e. Possibility of a third charging point on the public road in front of the laboratory.
- CAMPUS DESIGN. The second unit is located in the town of Calenzano, near the UNIFI building, on public land and includes:
    a. Two DC charging points, with characteristics suitable for the latest bidirectional charging technologies (“V2G ready”), with indicative power of 25kW, acquired on the market from suitable operators.
    b. Two additional stations available prepared for the installation of two charging points, currently under development during the project itself.

The control system proposed by UNIFI will manage the energy between the two stations as if the two units belonged to the same location, following a logic of minimizing the impact on the electricity grid based on the availability of the photovoltaic system and other elements. This logic corresponds to the functioning of an “energy community”. While waiting for the authorizations for the creation of the Community in operational terms, this method will be emulated through software systems.

All installations in areas open to the public will correspond to commercial and/or pre-series products that fully comply with the safety regulations and product directives required for the sector. To this end, three potential suppliers of charging equipment have been identified:

- ABB, partner in XL-Connect.
- CIRCONTROL, partner in XL-Connect.
- SILLA, commercial supplier of V2G-ready systems.
- ONCHARGE, able to supply the devices and guarantee complete installation.

The charging points will be entirely compatible with vehicles suitable for the CCS type 2 standard, and in order to ensure a minimum number of events for the experimentation, some commercial V2G ready vehicles will be rented (e.g. Volkswagen ID4). The energy may be supplied by ESTRA, XL-Connect's partner, under conditions different from the usual energy trade, as they belong to the experimentation.

Figure 25 Geographical location of the two demonstration sites.

MOVING LAB specifications		
Charging unit		
Chargers	At least 2	
AC Type	1x AC	≥ 11 kW
DC Type	1 x DC CCS (V2G ready)	≥ 20 kW
Protection	External Environment	
Position	Private area (Parking University of Florence)	
Energy production Unit		
PV Roof	External structure - covering at least 2 parking lots	
PV System	15m^2 – nominal power 3.5 kW	
Energy storage	Battery and 3-phase inverter	5-10 kWh
Protection	For external environment	
Type of area	Private area (Parking University of Florence)	

Table 6. UNIFI MOVING LAB specifications.

DESIGN CAMPUS specifications

Charging unit		
Chargers	At least 3	
AC Type	1 x AC	≥ 11 kW
DC Type	2 x DC CCS (V2G ready)	≥ 20 kW
Protection	External Environment	
Type of area	Public Area (Calenzano municipality)	

Table 7. UNIFI DESIGN CAMPUS specifications

3.5.3. ABB Demonstration

The demonstrator that will be realised in ABB factory placed in San Giovanni side is the main goal of XL-Connect project and it'll be one of the first of its kind; a cutting-edge microgrid plant seamlessly integrated with PV solar array, advantage storage system and V2G DC ABB's bi-directional charger. This charging solution leads to smarter energy and emission-free mobility strategies that results in better connected and more cost-effective. This microgrid not only powers itself independently, thanks to PV contribution and ESS energy, but also remains connected to the main grid for optimal power management.

In this case study the grid will feed energy to a parking space near the factory to provide energy to company vehicle fleets as to prove that microgrid will be a good solution for large parking area; that comprehends interesting conditions which suggest their suitability for the implementation of smart or even bidirectional charging logic, due to the variability of the loads and the availability of many storage batteries located into EVs.

This parking area is already equipped with a dedicated lot for parking and recharging heavy duty vehicles. The chargers will be the same kind, CCS equipped, but the bigger capacities of those batteries will lead to higher charging time compared to EV's.

The main goals are:

1. Expand the knowledge and the culture related to EV's energy and power flow management.
2. Support the transition to EV's by providing energy on non-profit terms for the supplier.
3. Impact on the factory side installing EV's charging points directly on site.

Here the target will be to realize a "stand-alone" microgrid which will be able to operate disconnected from the main grid and ensure the recharge of the vehicle fleet; it'll be possible due to PV plants, that provide energy directly used for the EVs charge or for recharge the ESS, and in case of relevant load the storage will provide the remaining amount of energy. On the other hand, when the microgrid is connected to the main grid, another main goal is to ensure the contribution to the grid stability by feeding energy back, using the storage battery of the connected vehicles, thanks to V2G chargers and ESS storage. During the transient mode V2G chargers will be able to manage the transition during micro grid re-connection, aligning frequency and voltage to main grid's values, and facilitating linking operations.

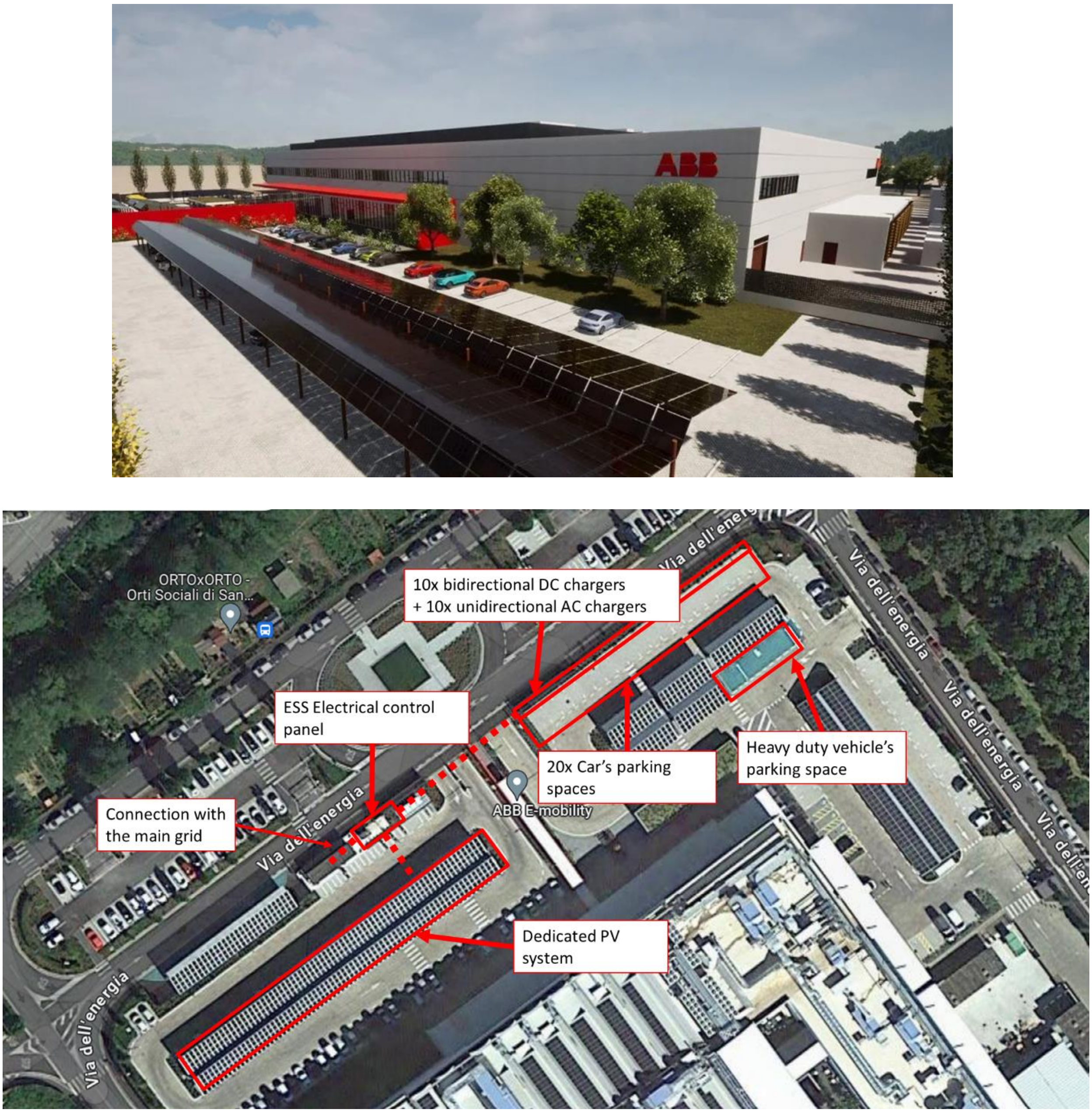

Figure 26 Street view of the ABB-Demonstrator plant and the grid configuration.

3.5.3.1. System Description

With the integration of bidirectional chargers this microgrid has upgraded the capacity to feed energy back to the main grid, facilitating energy sharing functions, to reduce the power absorbed from the main grid; thus, paving the way for a more efficient and resilient energy system accomplishing the operational congestion management logic. The surplus energy given by PV plants can be sent back into the grid and it can be used to charge the internal battery of ESS during low-demand hours allowing "Load Time-of-Use shifting". Furthermore, the industry side has a high energy consumption, with power peaks, which can be reduced by peak shaving strategies. It's also possible to implement load levelling strategies that flatten the load curve during the day and also to reduce the amount of energy taken from the main grid during peak hours.

Both strategies are based on the energy storage into battery's ESS during low-price hours and, in case of high energy consumption during the high-price hours, the energy stored will be redispatched for avoid grid overload or obtain economical revenue to offset the cost of energy. Additionally, costs to electric ratepayers are further reduced by limiting congestion on existing distribution infrastructure avoiding costly distribution system upgrades.

This system allowed to size the PV solar plant related to ESS storage size, that will ensure a certain time of stand-alone mode operation providing back-up power, and the bidirectional flow of energy through micro and main grid allows to feed surplus energy to other loads (e.g. chargers, factory loads...) located also in the plant but externally respect to the micro grid. V2G can provide economic advantages for large operators who are able to get remuneration for grid services, storage energy during low-demand hours and send it back during peak-demand to obtain an economic revenue. Smart grids benefit by maximising their use of renewables and optimising their carbon footprint in real time. In addition, EVs can help to store the excessive energy produced by a high amount of intermittent renewable energy sources; the EV's batteries can contribute to provide energy to the network in case the demand overcomes the production (emergency power supply), mitigating grid bottlenecks and minimising grid volatility. The developments enabling bidirectional charging to a large number of EV users in the near future will allow to enable functions for grid stability like peak shaving and load leveling. The contribution of ESS and EVs are becoming an active part of the network. This approach will allow to size the plant with respect to the medium value of the load, instead of the maximum power, as the peak loads will be fulfilled by the energy taken from parked vehicles for long-term congestion management. The ESS system present into the microgrid contributes to fulfill the power demand in case of needs, ensure a stable and always linked power source; the microgrid can contribute injecting or absorbing reactive and active power to ensure and maintain constant voltage and frequency values. The energy storage system is charged or discharged in response to an increase or decrease of grid frequency and keeps it within pre-set limits. Intermittent power generation from renewables and other sources, along with variable loads, cause deviations from nominal frequency in the grid. Energy storage systems could restore the balance between supply and demand.

Other advantages would be redispatch and local power injection to reduce energy losses in the main grid and facilitate DSO and TSO dispatch and load flow planning by increasing Behind-the-meter charging power. Another important fact related to V2G is the battery degradation due to more frequently charging and discharging cycles; it could be causing higher battery degradation. The main open issue is to model this phenomenon accurately and to estimate in the right way the extra decay of storage capacity.

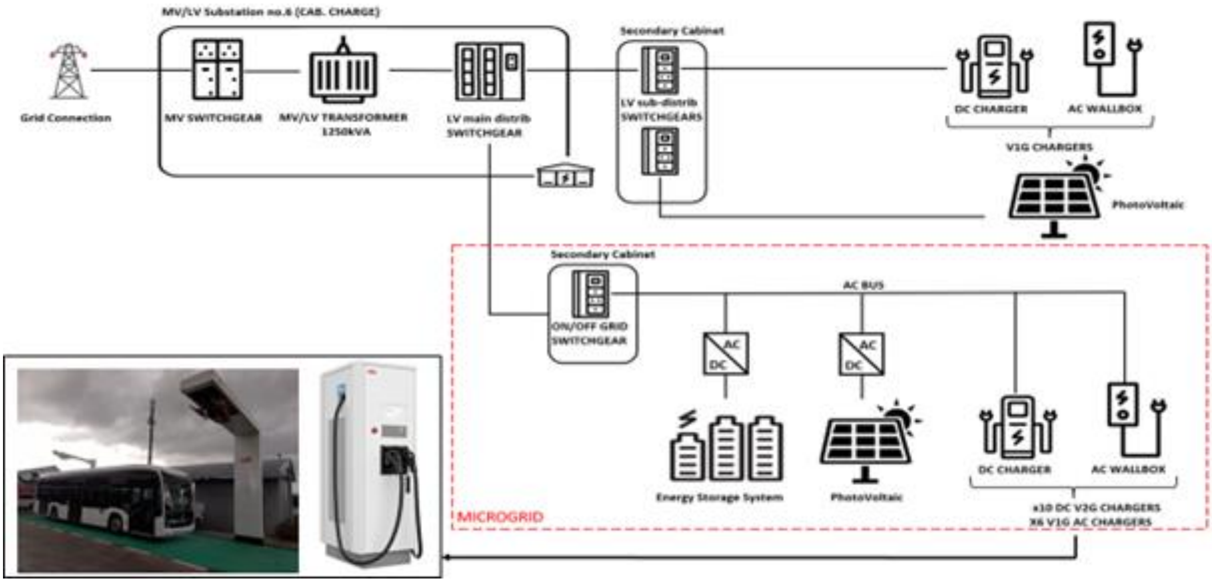

Figure 27 System description.

Item and Related Features					
Charging Points					
	Number	**Size**	**Typology**	**Connector**	**Protocol Communication**
Bi-directional Chargers, V2G	10	11 kW	DC Three-Phase	CCS2	OCPP, 4G, BT, Ethernet, LANx2
Monodirectional Chargers, V1G	6	3,6 - 11 kW	AC /DC Three-Phase	CHAdeMO, CCS	OCPP, CHAdeMO, 4G, BT, Ethernet, LANx2
Microgrid System-Energy Storage Based					
Capacity [kWh]	96.8 kWh				
Power [kW]	97 kW				
Maximum Discharging Power	<92 kW				
Features	LUNA 2000 97kWh-1H1 Storage energy produced by PV System or drained from the main grid and it's linked with Solar Inverters, PV Plants, Chargers and Plant Grid.				
PV Solar Panels					
Model	Q.PEAK DUO XL-G9.3 440-460				

Installed Power [Wp]	460 Wp (for each module)
Dimensions and Modules [-]	2163 mm × 1030 mm × 35 mm (including frame) 284 modules
Solar Inverters	
Model	SUN2000-36KTL-M3
Efficiency	98.4%
Number of MPPT	4
Max AC Active Power	36,000 W

Table 8. ABB demonstrator main features.

3.5.3.2. Time Planning

The deadline for realizing this demonstration action is set on June 2024, according to EU planning related to XL-Connect.

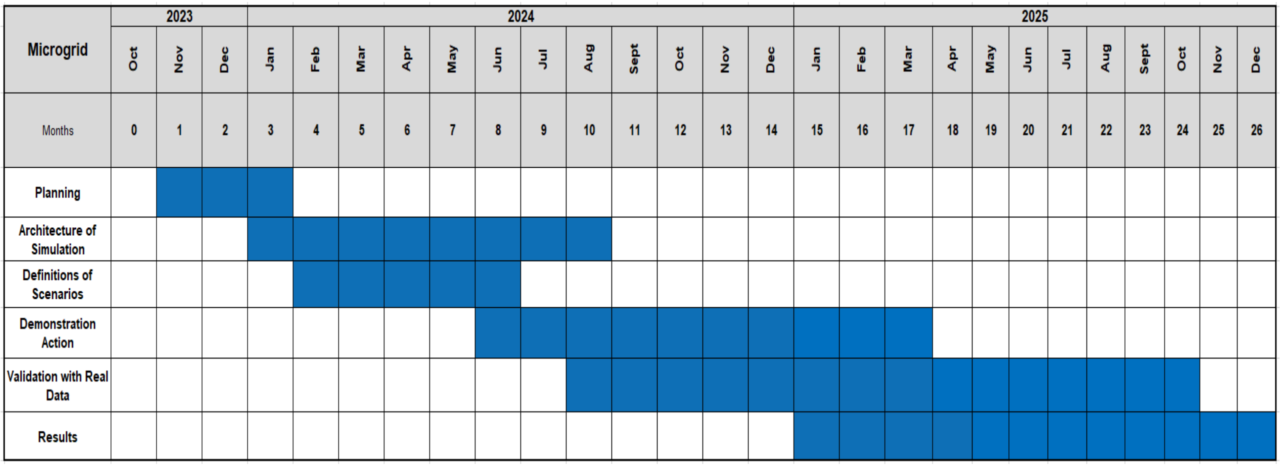

Figure 28 Gantt plan.

3.5.3.3. Scalability and Conclusions

Related to the real demonstration it would be replicated and scaled for higher amount of power, between 100kW and 1 MW, maintaining the same configuration but sizing up the ESS storage battery, numbers of V2G chargers and increasing the total amount of PV solar plant installed. Instead of this it'll be also necessary to re-size inverters and evaluate the possibility to increase the number of Maximum Power Point Tracking (MPPT) to optimize the solar production, based on solar plant extension and location as we'll implemented in ABB plant at San Giovanni Valdarno, Italy. It also could be used to test charging logic, implementing different strategies and priority recharging based on revenue and a tradeoff between battery aging and user's revenues needs and availability.

Additionally, this real demonstration can be extended and implemented on different software to simulate various scenarios related to user's behavior, island mode reconnection and on grid mode, variation of ESS storage level and solar irradiation. Future main goal of the demonstration action is to implement a DC microgrid virtual model, based on results obtained from AC ones, for comparison and to prove the scalability of the system.

The preliminary expected results are related to the comparison between AC and DC grid analyzing aspects like microgrid efficiency, grid requirements and compliance codes for bidirectional chargers, variability of RES power and internal grid's power flow.

Main goals are to demonstrate that the difference between AC and DC microgrids would be small, since the efficiency of ABB chargers are reach 99%. This high efficiency determines a reduction of power loss during the conversion and will lead to eliminating the constraints about the kind of energy used into the microgrid. Another challenge is to verify and validate the accomplishment of relevant grid requirements and compliance codes for bidirectional chargers and then compare them; related to this it'll be evaluated how, and which technical features will be used to achieve the requirements and its feasibility. Related to smart charging concepts, for both AC and DC microgrids, the different aspects in different environments including low power renewable energy sources will be compared.

Another interesting point will be understanding and analyzing the energy system and power grid based on bidirectional chargers for both AC and DC microgrids and evaluate how they will behave in the future. Interesting KPIs for this demonstration action are included in the *Social Category*:

- *Customers' Satisfaction:* these are a type of metric that businesses use to gauge how happy or satisfied their customers are. It is a key metric for any business that wants to improve customer loyalty and retention. Customer satisfaction score is a measure of how satisfied a customer is with a product or service.
- *Evaluation of Cost of Electricity Bills:* evaluation of price policies with respect to the previous bills when the microgrid wasn't up and running yet.

Others interesting KPI belong to *Technical Category*:

- *Voltage Deviation*: measure how much the gap is between the actual voltage supplied to MV/LV users and the nominal value.
- *Harmonic Distortion:* measure the distortion that affects signals caused by conversion stage.
- *On-site Energy Ratio:* relation between the annual energy supply from local renewable sources and the annual energy demand.

- *Degree of self-supply (RES):* percentage of self-generated energy not injected to the grid. It allows us to estimate the percentage of energy that will be produced from PV plants, and it represents the part share not taken from the grid.
- *Peak Load:* curtailment of the peak power by load shift or load-shedding thanks to ESS Energy Flow Management System.

3.5.4. ABEE Demonstration

The primary goal of the demonstration is sector coupling, involving the seamless integration of electric vehicles (EVs) and the electricity grid with hybrid renewable energy systems and storage components such as EVs, photovoltaics (PV), electric grids, electrolyzers, hydrogen storage, and fuel cells. In this virtual showcase, sector coupling is designed to achieve a 20% improvement in energy efficiency, a 10% reduction in power losses (eliminating energy/power flow from the distribution sector), and a 2% enhancement in power quality. Notably, the inverter connected to the DC link and grid can regulate injected reactive and active power precisely where needed.

The innovation in this demonstration lies in integrating multiple energy sources, storage systems, conversion technologies, and charging systems. The key focus is optimizing energy and power flows to effectively address fluctuations in renewable energy generation and uncertainties associated with EV energy demand. The demonstrator comprises an EV emulator with a 10 kW charger, a 5 kWp photovoltaic system, an electric grid connection, a 2 kW hydrogen electrolyzer, a 55L hydrogen tank and a 5 kW fuel cell, all interconnected, as illustrated in Figure 29 and Figure 30.

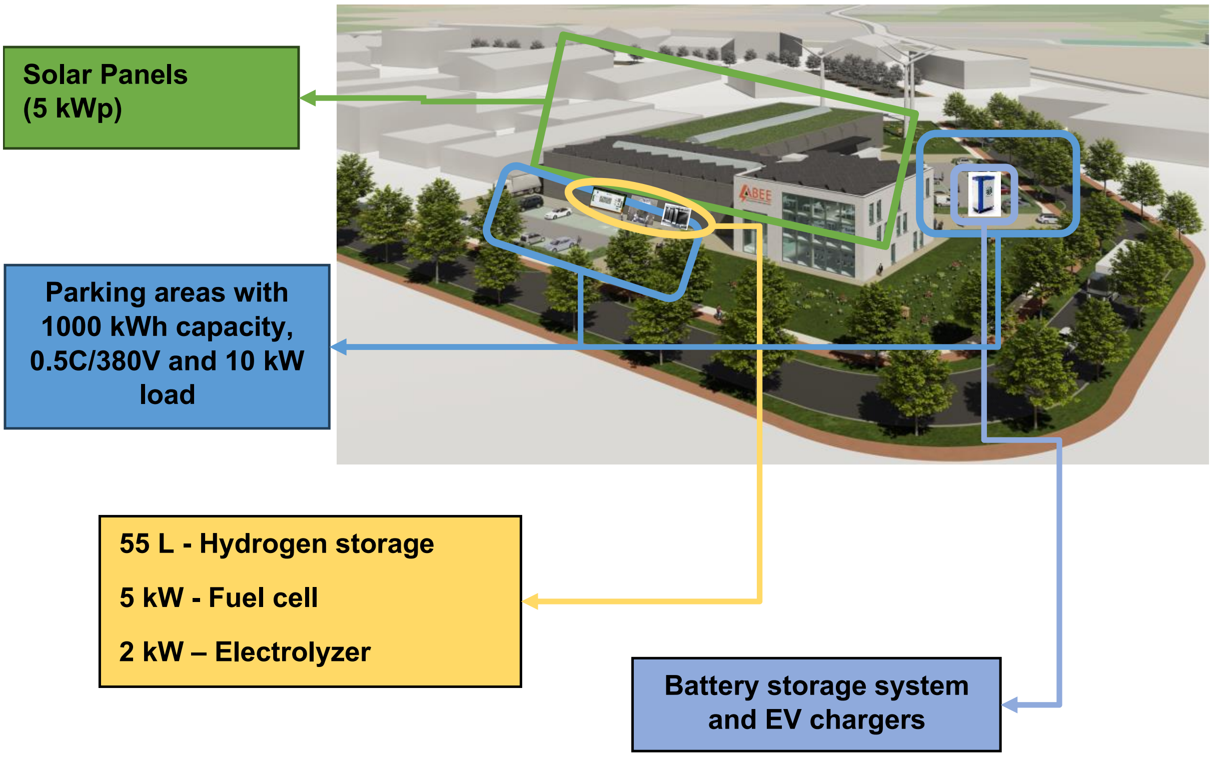

Figure 29 Demonstration site at ABEE, Belgium.

3.5.4.1. System Description

The system is comprised of a sector-coupled unit situated at the ABEE headquarters premises in Ninove, Belgium. Depending on the implementation methods, it can function either as an "individual remote self-consumer of renewable energy" or as a "remote active customer utilizing the distribution network." This demonstrator is intended to serve as both a real-world and virtual showcase.

Key specifications include:

- Limited access to the unit at ABEE headquarters, restricted to ABEE employees.
- A bidirectional DC charging point with an indicative power load of 10 kW.
- Charging is facilitated through a hydrogen and photovoltaic system, featuring an expected nominal power output of approximately 10 kW.
- Control system enabling communication, monitoring, and remote control via EMS (Energy Management System) and PMS (Power Management System).
- Storage system utilizing batteries with a capacity ranging from 5 to 10 kWh and a hydrogen fuel cell with a capacity of 5 kW.

The schematic below illustrates the demonstration setup, and tables 9 through 12 provide detailed technical specifications for the PEM electrolyser, hydrogen fuel cell, photovoltaic cells, and converter.

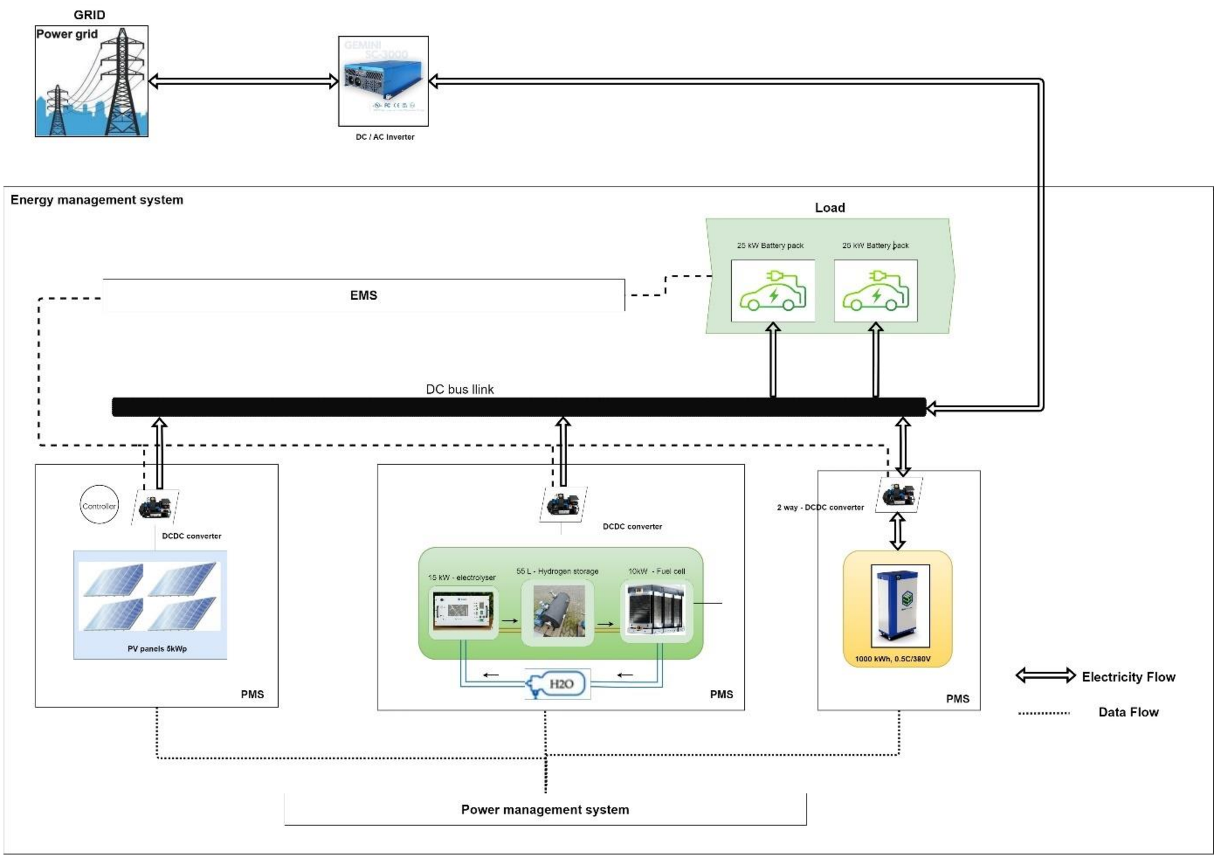

Figure 30 Schematic of the sector coupling demonstration at ABEE in Belgium.

Technical data of Electroyser	Alkaline LBEX-5K	PEM LBEX-P2K
H_2 production rate	1 Nm³/h	0.4 Nm³/h
Purity	99.9 %	99.9%
O_2 flow rate	0.5 Nm³/h	0.2 Nm³/h
Water flow rate (LPM)	1 - 1.5	1 - 1.8
Dimensions (L x W x H mm)	1000 x 550 x 1200	550 x 374 x 580
Ambient temperature	2°C to 40°C	10°C to 40°C
Electrolyte	KOH solution	Proton exchange membrane
Weight (kg)	100	45

Table 9. Specification of the candidate hydrogen production electrolyzer.

Technical data of 5 kW hydrogen fuel cell	
Weight	45 kg
Dimensions	720 x 480 x 370 mm
Fuel	Hydrogen
Type of Fuel cell	PEM
Max Power	5.5 kW

Nominal Power	5 kW
Max output voltage	115 V
Max current	80 A
Type of cooling	Air cooled

Table 10. Specifications of the candidate hydrogen fuel cell.

Technical data of solar cells	
Moder	SH-400S6-24
Maximum Power at STC	400 W
No of panels	12
Optimum operating voltage	38.5 V
Optimum operating current	10.13 A
Open-circuit voltage	46.3 V
Short-circuit current	10.87 A
Solar cell efficiency	20.34 %
Solar module efficiency	18.04 %
Operating temperature	-40 to 85ºC
Maximum system voltage	DC 1000
Maximum series Fuse rating	15A
Power Tolerance	0 to +3%
Warranty on product	10 years -- product
Warranty on power	25 years -- power

Table 11. Specifications of the candidate solar panels.

Technical data of 5kWp converter for solar power	
Power	5 kW
Solar Charge type	MPPT
Max. PV array Power	5000 W
Max. PV array Open circuit	500VDC
PV Array MPPT voltage range	120VDC to 450 VDC
Max. Solar charge current	80A
Position	External
Peak efficiency	97 %
Nominal Voltage	220/230 VAC+5%

Table 12. Specifications of candidate 5 kW inverter used for solar system.

Depending on the availability of power from the photovoltaic system, solar energy is utilized to produce hydrogen through an electrolyzer. The generated hydrogen is then stored in a 55 L tank in compressed form. The storage duration for hydrogen can vary from days to weeks, depending on power demand. Simultaneously, hydrogen fuel cells are employed to generate electricity using the stored hydrogen, which is subsequently stored in battery packs. The stored energy in the battery packs is used for charging electric vehicles (EVs). This entire process is bidirectional, allowing energy flow from the grid to the EV/battery storage system and vice versa (Vehicle-to-Grid, V2G). Presently, approximately 7 to 12 charging points are to be installed in the ABEE location's parking area. Solar panels, hydrogen fuel cells, or the power grid under different conditions can supply energy or electricity.

Strategies for the demonstration action:

- Procurement process for acquiring equipment, including obtaining and reviewing quotations before finalization.
- Conduct a separate dry run of the equipment, if feasible.
- Integrate the equipment into the local DC grid and initiate operation without optimization.
  Exercise caution regarding power fluctuations and conduct testing for safety protection and communication systems.
- Set up XL-connection algorithms and controllers, ensuring a thorough understanding of the algorithms.
- Integrate XL-connection algorithms and controllers, subjecting them to intensive testing under various scenarios for a demonstration.

3.5.5. Porto, Coimbra and Setúbal (Portugal) Demonstrations

The Portuguese demonstration will assess electric mobility capabilities with smart charging mechanisms. It aims to explore new EVs' usage patterns at the individual level (e.g., commuting to work) and at the businesses' level (e.g., EVs used for business maintenance and operations). Furthermore, a set of OpenAPI specifications (developed within T3.2) will be demonstrated allowing for the communication between system operators and smart charging involved entities/devices, namely the interaction with Circontrol's local charging controller and the existing charging systems that will be used in the Portuguese demonstration to enable the mobilization and activation of flexibility through the use of smart charging mechanisms developed within the project and the necessary bidirectional data exchange. These efforts will be done resorting to part of E-REDES own EVs fleet, both from working service and personal use (PUV), and several charging stations with different charging speeds, ranging from slow charging to (ultra-)fast charging. These resources will be also paired with specifically chosen demonstration locations that include buildings with renewable generation, residential housing, and offices.

3.5.5.1. Objectives

The objectives of this demonstration action are:

- Explore EVs' usage patterns at the individual and at the businesses' level to understand grid impacts and flexibility needs, making use of clustering and forecasting techniques supported by data to be collected in the demonstration, and extrapolated to address large scale EV adoption future scenarios.

- Demonstrate the potential of combined approaches between system and EV charging needs, in different timeframes, ranging from planning activities to real time operation.

- Ensure interoperability through the development of a set of OpenAPI specifications, to ensure the open communication between system operators and smart charging related entities/devices to foster neutral market developments and a broader range of options that serve the user as well as the system needs.

3.5.5.2. Main demonstrated XL-Connect Innovations

- Clustering of the electricity system based on the electric mobility real and forecasted adoption and usage.

- Applied methodologies to characterise and forecast grid flexibility needs to leverage the use of EVs smart charging and V2G capabilities both for planning and operational activities.
- A set of use cases that cover smart charging (and V2G) and the provisioning of flexibility to the system.
- Interoperable solutions between DSO and charging platforms based on universal and open solutions.

3.5.5.3. Study Cases

Operational Interoperability

The aim is to enable electric mobility-related platforms/entities to communicate with different brands of commercial chargers (interoperability with existing chargers, not prototypes) and with the DSO to optimise charging processes depending on the types of use.

E-REDES intends to implement the best smart-charging (and V2G practices) within the scope of corporate electric mobility. In this sense, the aim is to test the maximum number of different UCs for EVs use that provide for the DSO-CPO-charger relationship.

For this, the "client with restrictions" figure will be tested. This figure, present in the legislation and regulations of the Portuguese Energy Services Regulatory Authority (ERSE), represents a specific client that is allowed to connect to the grid with the prerogative of being available to disconnect or limit its power when necessary. Based on this figure, the following operational UCs will be tested:

1. The DSO receives information about how much the CPO is consuming (or injecting).
2. Confirm correct reception of voltage, power, etc. by the DSO.
3. When there are limitations, the CPO receives an order from the DSO to limit, cut (or inject).
4. Contingency regime: when the DSO notices a frequency problem (black out) asks the CPO for help.

An additional dynamic charging allocation UC will be tested for the evaluation of different charging models depending on energy availability. Namely, the CPO will receive an order from the DSO to consume when there is a momentary excess (during a restricted period of time) of energy in the network.

Planning technical challenges

The upcoming dominant electrical mobility will impose major challenges for DSOs, such as guaranteeing the needed charging infrastructure and a secure and reliable system operation capable of mitigating grid congestion and voltage violation events, ensuring that everyone is served with the expected QoS. A significant change in the way DSOs plan and operate the electricity grid is required and precise planning processes to predict the future needs are crucial.

By exploring EVs' usage patterns at the individual level and at the businesses' level and making use of the tools and knowledge acquired within the scope of other project activities, namely within WP2, the following research questions will be investigated:

- How to model the overall impact on LV networks associated with the electrification of energy consumption and increase in self-consumption?
- How to distribute this impact across different networks (rural, urban), with great uncertainty regarding the overall impact and its distribution across different levels of urbanization, wealth, etc.
- How to model flexibility and into network planning processes (who will use it?)
- How to compare new solutions (flexibility, V2G) with traditional ones (grid reinforcement/expansion)?
- Is flexibility sufficient? Or must we also foster V2G solutions? What is the value of V2G?

3.5.5.4. Locations and Equipment

By selecting cities in the North, Centre and South regions, the aim is to promote a constant flow of charging and encourage corporate electric mobility.

The UCs previously described will be implemented in 3 E-REDES offices and 5 households described below, already equipped with chargers of different brands and power. An extra location will be selected to be equipped with a commercial (ultra-) fast charger to be acquired and adapted.

E-REDES offices

The selected locations include offices where both PUV, which charge during the day, and service vehicles, which charge at night, are used. All chargers are currently connected to a mobility platform and allow for smart-charging. Two of the locations (Coimbra and Setúbal) are also equipped with PV panels.

<table>
<tr><th>City</th><th>Location</th><th>No. of sockets</th><th>No. of chargers</th><th>Type of sockets</th><th>Charger brand</th><th>No. of service EVs</th><th>No. of e-PUV</th></tr>
<tr><td>Porto</td><td>Amial</td><td>6</td><td>3</td><td>Type 2</td><td>Alfen 22kW</td><td>8</td><td>0</td></tr>
<tr><td rowspan="2">Coimbra</td><td rowspan="2">Rua do Túnel</td><td>4</td><td>2</td><td>Type 2</td><td>Alfen 22kW</td><td rowspan="2">4</td><td rowspan="2">2</td></tr>
<tr><td>4</td><td>4</td><td>Type 2</td><td>Etrel PRO 22kW</td></tr>
</table>

Setúbal	SE de São Sebastião	16	8	Type 2	Alfen 22kW	22	1
		1	1	CHAdeMO	EFACEC 45kW		

Table 13. Demonstrators specifications.

Figure 31 SE Vale de Mulatas - Setúbal.

Figure 32 On the left Rua do Túnel - Coimbra. On the right Amial - Porto.

E-REDES workers' households

5 households (including E-REDES workers' households) in Porto municipality equipped with MOON ID 7.4kW (single-phase) chargers [62], using OCPP 2.0J and EEBus communication protocols.

4. Real Demonstration Actions: Risks and Preventative Measures

The risks associated with the real demonstrations are divided in two categories: organisational risks, re-grouping the procurement of demonstrator parts and needed authorizations and technical risks, regrouping all risks associated with the deployment of the demonstration. The different risks associated to these two groups and possible preventive actions are described in the following.

List of organisational risks:

- Availability of bidirectional EVSE is limited: The demonstrators focus on the implementation of bidirectional charging and the optimizing of the charging strategy. Therefore, it is essential for the demonstrators to have reliably working EVSE with bidirectional capabilities at hand. Currently, the list of commercially available EVSE that have these capabilities is limited. In addition, the procurement of bidirectional charging stations is done by each demonstration on their own, since the requirements can slightly change depending on the demonstration. Therefore, several producers need to be contacted by the project partners in order to guarantee the in-time arrival of the best possible EVSE for their demonstration.

- Public/Private EVSE: The public and private demonstration each come with their own up- and downsides. For public demonstration, the acquisition of the licenses for installing the EVSE and providing the charging management strategy can be a tedious task due to the bureaucratic effort. In addition, the testing capabilities of these demonstrators are limited since people from the public demand to charge their EV and the EVSE must work at all times. Therefore, the possible use-cases are limited.
  For private demonstrations on the other hand, one problem is the access to realistic user data. Since their EVSE will only be used by a limited amount of people, it could get challenging to collect enough user data during the period of the demonstration.
  Therefore, the demonstration features both public and private demonstrations. During the demonstration period it is therefore essential to have a working data exchange between the demonstrations. This allows for the private demonstrations the receive user data from the public ones and for the public ones to receive feedback regarding their charging management tested on the private ones.

List of technical risks:

- Interoperability of EVSE and EV for bidirectional DC-Charging: Uni-directional charging at public EVSEs is currently still leading to unexpected problems for EV users, the most frequent problems occurring at the start of the charging process [63]. Beside the problem of different types of plugs and connectors, the use of different communication protocols for each standard increases the incompatibility of EVSEs and EVs [64]. In addition, bidirectional charging also requires the implementation of new functionalities into the charging protocol, which could expand these problems. Although standardised protocols to overcome these issues are being developed, the widely adoption in EVSE and EV is still far in the future. One risk associated with the demonstrations in the XL-Connect project is the low availability of compatible EV with the EVSE purchased. To ensure that sufficient charging processes take place to evaluate these, it is essential to put the charging stations into operation early in order to maximize the runtime over the project duration and at the same time to report possible problems to the EVSE developers in order to enable quick updates.

- Resulting grid instabilities: Some of the demonstrations shall be used for the application of grid frequency control. A fast and accurate controlling of the EVSE is indispensable for these applications. A miss-timed or wrong controlling of these EVSE could lead to increased local grid instabilities instead of reducing them. Even though the resulting negative impacts are limited due to the small amount of EVSEs available for the demonstrations, these effects still need to be reduced. One countermeasure to ensure the reliable and effective functionality is extensive testing of the algorithms during simulations beforehand.

- Other risks: Beside the risks mentioned before, several other technical risks go along with the operation of EVSE, like the risk of vandalism of the EVSE, the safety of the charging data from users or the unsatisfaction of the users in case of a failed charging process. These risks are mainly coupled with public charging stations in general and not especially to the controlling of bidirectional charging stations. In consequence, the counteractive measures lie mostly on the EVSE providers. To minimize them, early discussions and addressing of these issues with the EVSEs producers are necessary. In addition, the users shall be sensitized that the EVSEs are part of a research project via appropriate signage.

Acknowledgments

This document reflects only the author's view. The commission and the CINEA Agency are not responsible for any use that may be made of the information it contains.

References

[1] S. Englberger, K. Abo Gamra, B. Tepe, M. Schreiber, A. Jossen, and H. Hesse, 'Electric vehicle multi-use: Optimizing multiple value streams using mobile storage systems in a vehicle-to-grid context', *Applied Energy*, vol. 304, p. 117862, Dec. 2021, doi: 10.1016/j.apenergy.2021.117862.

[2] D. Göhlich and A. F. Raab, Eds., *Mobility2Grid - Sektorenübergreifende Energie- und Verkehrswende*. in Energie- und Mobilitätssysteme der Zukunft. Berlin, Heidelberg: Springer, 2021. doi: 10.1007/978-3-662-62629-0.

[3] H. C. Hesse, M. Schimpe, D. Kucevic, and A. Jossen, 'Lithium-Ion Battery Storage for the Grid—A Review of Stationary Battery Storage System Design Tailored for Applications in Modern Power Grids', *Energies*, vol. 10, no. 12, Art. no. 12, Dec. 2017, doi: 10.3390/en10122107.

[4] A. Thingvad *et al.*, 'Value of V2G Frequency Regulation in Great Britain Considering Real Driving Data', in *2019 IEEE PES Innovative Smart Grid Technologies Europe (ISGT-Europe)*, Sep. 2019, pp. 1–5. doi: 10.1109/ISGTEurope.2019.8905679.

[5] Energiewirtschaftliches Institut an der Universität zu Köln gGmbH (EWI), 'Entwicklung der Momentanreserve und Abschätzung des Bedarfes an Fast Frequency Response im Europäischen Verbundsystem', 2020. [Online]. Available: https://www.ewi.uni-koeln.de/cms/wp-content/uploads/2020/02/20200302_EWI-Studie_Momentanreserve_und_FFR.pdf

[6] F. Braeuer, J. Rominger, R. McKenna, and W. Fichtner, 'Battery storage systems: An economic model-based analysis of parallel revenue streams and general implications for industry', *Applied Energy*, vol. 239, pp. 1424–1440, Apr. 2019, doi: 10.1016/j.apenergy.2019.01.050.

[7] Datta Vhanmane, 'Revolutionizing the Energy Grid: The Power of Vehicle-To-Grid Technology'. Accessed: Nov. 30, 2023. [Online]. Available: https://www.linkedin.com/pulse/revolutionizing-energy-grid-power-vehicle-to-grid-datta-vhanmane/

[8] B. Goia, T. Cioara, and I. Anghel, 'Virtual Power Plant Optimization in Smart Grids: A Narrative Review', *Future Internet*, vol. 14, no. 5, Art. no. 5, May 2022, doi: 10.3390/fi14050128.

[9] European Parliament and Council, 'Directive (EU) 2018/2001 of the European Parliament and Council on the promotion of the use of energy from renewable sources', *Official Journal of the European Union*, 2018, Accessed: May 20, 2023. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=fr

[10] ‘Energy communities and renewable energy sources’, Inycom Energy. Accessed: Nov. 30, 2023. [Online]. Available: https://inycomenergy.com/en/energy-communities/
[11] European Commission and Directorate-General for Energy, ‘Clean energy for all Europeans’, *Publications Office*, 2019, [Online]. Available: https://data.europa.eu/doi/10.2833/9937
[12] M. L. Di Silvestre, M. G. Ippolito, E. R. Sanseverino, G. Sciumè, and A. Vasile, ‘Energy self-consumers and renewable energy communities in Italy: New actors of the electric power systems’, *Renewable and Sustainable Energy Reviews*, vol. 151, p. 111565, Nov. 2021, doi: 10.1016/j.rser.2021.111565.
[13] M. Krug, M. R. Di Nucci, M. Caldera, and E. De Luca, ‘Mainstreaming Community Energy: Is the Renewable Energy Directive a Driver for Renewable Energy Communities in Germany and Italy?’, *Sustainability*, vol. 14, no. 12, Art. no. 12, Jan. 2022, doi: 10.3390/su14127181.
[14] E. Caramizaru and A. Uihlein, ‘Energy communities: an overview of energy and social innovation’, JRC Publications Repository. Accessed: May 25, 2023. [Online]. Available: https://publications.jrc.ec.europa.eu/repository/handle/JRC119433
[15] ‘SMARD | Übertragungsnetzbetreiber’. Accessed: Nov. 30, 2023. [Online]. Available: https://www.smard.de/page/home/wiki-article/446/205184
[16] ‘Interaktive Karte | Energy-Charts’. Accessed: Nov. 30, 2023. [Online]. Available: https://energy-charts.info/map/map.htm?l=de&c=DE&country=DE&zoom=11&lat=50.758&lng=5.945&lines=1010000
[17] ‘Interaktive Karte | Energy-Charts’. Accessed: Nov. 30, 2023. [Online]. Available: https://energy-charts.info/map/map.htm?l=de&c=DE&country=DE&zoom=13&lat=50.797&lng=6.133
[18] ‘Stromnetze mit Umspannwerken und detaillierter Infrastruktur’. Accessed: Nov. 30, 2023. [Online]. Available: https://www.flosm.org/de/Stromnetz.html?lat=50.7642661&lon=6.08506343&r=5599.1135&st=0&sw=cabledistributioncabinet,generator,powerbay,powerbiofuel,powerbiogas,powerbiomass,powerbusbar,powercoal,powercompensator,powerconverter,powergeothermal,powerhydro,powerline380k,powerline400k,powerline420k,powerline750k,powerline765k,powerlinedchigh,powernuclear,poweroil,powerpole,powersolar,powersubstation,powerswitch,powertidal,powertower,powerwaste,powerwind,transformer
[19] ‘ALEGrO’. Accessed: Nov. 30, 2023. [Online]. Available: https://www.amprion.net/Netzausbau/Aktuelle-Projekte/ALEGrO-Deutschland-Belgien/
[20] ‘STAWAG Stadtwerke Aachen AG | STAWAG Stadtwerke Aachen AG’. Accessed: Nov. 30, 2023. [Online]. Available: https://www.stawag.de/
[21] ‘Erneuerbare Energien | STAWAG Stadtwerke Aachen AG’. Accessed: Nov. 30, 2023. [Online]. Available: https://www.stawag.de/ueber-uns/erneuerbare-energien/
[22] C. Piselli, G. Salvadori, L. Diciotti, F. Fantozzi, and A. L. Pisello, ‘Assessing users’ willingness-to-engagement towards Net Zero Energy communities in Italy’, *Renewable and Sustainable Energy Reviews*, vol. 152, p. 111627, Dec. 2021, doi: 10.1016/j.rser.2021.111627.
[23] Parlamento Italiano, ‘Conversione in legge, con modificazioni, del decreto-legge 30 dicembre 2019, n. 162, recante disposizioni urgenti in materia di proroga di

termini legislativi, di organizzazione delle pubbliche amministrazioni, nonché di innovazione tecnologica', *Gazzetta Ufficiale della Repubblica Italiana*, 2020, Accessed: May 20, 2023. [Online]. Available: https://www.gazzettaufficiale.it/eli/id/2020/02/29/20A01353/sg

[24] D. F. Biagio and B. Basseghini, 'L'AUTORITÀ DI REGOLAZIONE PER ENERGIA RETI E AMBIENTE'. AREA, 2022. Accessed: May 20, 2023. [Online]. Available: https://www.arera.it/allegati/docs/22/727-22.pdf

[25] 'Comunità Energetiche | E-Distribuzione'. Accessed: May 25, 2023. [Online]. Available: https://www.e-distribuzione.it/a-chi-ci-rivolgiamo/casa-e-piccole-imprese/comunita-energetiche.html

[26] LEGAMBIENTE, 'Comunità Rinnovabili', *Rapporti 2022*, 2022, Accessed: May 20, 2023. [Online]. Available: https://www.comunirinnovabili.it/wp-content/uploads/2022/05/CR2022-2.pdf

[27] 'Comunità rinnovabili 2.0'. Accessed: May 25, 2023. [Online]. Available: https://experience.arcgis.com/experience/40737f090e95471aa87a300a43700bec?data_id=dataSource_2-service_65adaee296304bb793afd2f4197afe83_7708%3A199%2CdataSource_1-service_65adaee296304bb793afd2f4197afe83_5608%3A104

[28] K. Eroe, 'Comunità energetica "Solisca"', Comuni Rinnovabili. Accessed: May 25, 2023. [Online]. Available: https://www.comunirinnovabili.it/comunita-energetica-solisca/

[29] C. Scacchi, 'Solisca, la comunità energetica di Turano Lodigiano', The Good in Town. Accessed: May 25, 2023. [Online]. Available: https://www.thegoodintown.it/solisca-la-comunita-energetica-di-turano-lodigiano/

[30] J. Lowitzsch, 'Investing in a Renewable Future – Renewable Energy Communities, Consumer (Co-)Ownership and Energy Sharing in the Clean Energy Package', *Renewable Energy Law and Policy Review*, vol. 9, no. 2, pp. 14–36, Apr. 2019, doi: 10.4337/relp.2019.02.02.

[31] 'World Energy Trilemma Index | 2020', World Energy Council. Accessed: May 25, 2023. [Online]. Available: https://www.worldenergy.org/publications/entry/world-energy-trilemma-index-2020

[32] A. Poullikkas, G. Kourtis, and I. Hadjipaschalis, 'A review of net metering mechanism for electricity renewable energy sources', *International Journal of Energy and Environment (Print)*, vol. 4, Jul. 2013, Accessed: May 25, 2023. [Online]. Available: https://www.osti.gov/etdeweb/biblio/22188315

[33] Gestore Servizi Energetici, 'SERVIZIO DI SCAMBIO SUL POSTO', *Regole Tecniche - edizione IV*, 2019, Accessed: May 20, 2023. [Online]. Available: https://www.gse.it/documenti_site/Documenti%20GSE/Servizi%20per%20te/SCAMBIO%20SUL%20POSTO/Regole%20e%20procedure/Regole%20Tecniche%20Scambio%20sul%20Posto_2019.pdf

[34] S. Nan, M. Zhou, and G. Li, 'Optimal residential community demand response scheduling in smart grid', *Applied Energy*, vol. 210, no. C, pp. 1280–1289, 2018, Accessed: May 25, 2023. [Online]. Available: https://ideas.repec.org//a/eee/appene/v210y2018icp1280-1289.html

[35] K. M. Tan, V. K. Ramachandaramurthy, and J. Y. Yong, 'Integration of electric vehicles in smart grid: A review on vehicle to grid technologies and optimization techniques', *Renewable and Sustainable Energy Reviews*, vol. 53, pp. 720–732, Jan. 2016, doi: 10.1016/j.rser.2015.09.012.

[36] 'Decreto-Lei n.º 162/2019 | DR'. Accessed: Nov. 30, 2023. [Online]. Available: https://diariodarepublica.pt/dr/detalhe/decreto-lei/162-2019-125692189

[37] 'Comunidade Energia Simples - Energias Simples'. Accessed: Nov. 30, 2023. [Online]. Available: https://www.energiasimples.pt/produtores/comunidade
[38] 'Projeto "100 aldeias" já ultrapassou o objetivo e conta com mais de 140 comunidades de energia - Notícias - Ambiente Online'. Accessed: Nov. 30, 2023. [Online]. Available: https://www.ambienteonline.pt/noticias/projeto-100-aldeias-ja-ultrapassou-o-objetivo-e-conta-com-mais-de-140-comunidades-de-energia
[39] Welectric, 'Cleanwatts e Go Parity querem alargar projeto "100 Aldeias"', Watts On. Accessed: Nov. 30, 2023. [Online]. Available: https://welectric.pt/2022/09/14/cleanwatts-e-go-parity-querem-alargar-projeto-100-aldeias/
[40] 'Comunidades de energia | Goparity'. Accessed: Nov. 30, 2023. [Online]. Available: https://goparity.com/pt-pt/project/comunidades-de-energia-201
[41] Ordem dos Engenheiros, 'Comunidades de Energia: aplicações para o setor público e privado', 2022. [Online]. Available: https://www.ordemengenheiros.pt/fotos/editor2/15_02_2023_comunidadesdeenergia_ee.pdf
[42] Greenvolt, 'Greenvolt reforça liderança nas Comunidades de Energia com mais 11 MWp no Super Bock Group', Greenvolt. Accessed: Nov. 30, 2023. [Online]. Available: https://greenvolt.com/pt-pt/greenvolt-reforca-lideranca-nas-comunidades-de-energia-com-mais-11-mwp-no-super-bock-group/
[43] Martifer GROUP, 'Relatorio De Sustentabilidade', 2021. [Online]. Available: https://martifer.com/multimedia/martifer/pt/XdeX6XPPus-RSustentabilidade2021.pdf
[44] ERSE, 'Projetos-piloto aprovados ao abrigo do artigo 55.º do Regulamento do Autoconsumo', 2021. [Online]. Available: https://www.erse.pt/media/e1sldxhi/projetos-piloto_pt_com-links_01_2023.pdf
[45] 'ERSE aprova projeto-piloto de comunidade de energia renovável na ilha da Culatra', Universidade do Algarve. Accessed: Nov. 30, 2023. [Online]. Available: https://www.ualg.pt/erse-aprova-projeto-piloto-de-comunidade-de-energia-renovavel-na-ilha-da-culatra
[46] SONAE, 'SONAE E SONAE CAPITAL INTEGRAM PROJETO EUROPEU QUE VAI INVESTIR 25 MILHÕES DE EUROS EM LABORATÓRIOS DE SUSTENTABILIDADE', 2022. [Online]. Available: https://www.sonae.pt/fotos/press_releases/20220118_pr_projeto_probono_vf_210419094861e6fc6b4eec0.pdf
[47] ECO, 'Sonae transforma Campus da Maia em laboratório de inovação sustentável', ECO. Accessed: Nov. 30, 2023. [Online]. Available: https://eco.sapo.pt/2022/01/18/sonae-transforma-campus-da-maia-em-laboratorio-de-inovacao-sustentavel/
[48] 'INESC TEC participa no primeiro "living lab" de energias renováveis no Porto', INESC TEC. Accessed: Nov. 30, 2023. [Online]. Available: https://www.inesctec.pt/pt/noticias/inesc-tec-participa-no-primeiro-living-lab-de-energias-renovaveis-no-porto
[49] ERSE, 'Projetos-piloto aprovados ao abrigo do artigo 55.º do Regulamento do Autoconsumo (Regulamento n.º 373/2021, de 5 de maio)', 2021. [Online]. Available: https://www.erse.pt/media/vt3lhlap/lista_ppiloto_cer_pt_14122022.pdf
[50] K. Angelakoglou, K. Kourtzanidis, P. Giourka, V. Apostolopoulos, N. Nikolopoulos, and J. Kantorovitch, 'From a Comprehensive Pool to a Project-Specific List of Key Performance Indicators for Monitoring the Positive Energy Transition of Smart Cities—An Experience-Based Approach', *Smart Cities*, vol. 3, no. 3, Art. no. 3, Sep. 2020, doi: 10.3390/smartcities3030036.

[51] P. Ferreira *et al.*, ‘Assessing the societal impact of smart grids: Outcomes of a collaborative research project’, *Technology in Society*, vol. 72, p. 102164, Feb. 2023, doi: 10.1016/j.techsoc.2022.102164.
[52] M. Fotopoulou, D. Rakopoulos, and S. Petridis, *Development of a multi-dimensional Key Performance Indicators’ framework for the holistic performance assessment of Smart Grids*. 2022. doi: 10.5281/zenodo.7249154.
[53] D. Pramangioulis, K. Atsonios, N. Nikolopoulos, D. Rakopoulos, P. Grammelis, and E. Kakaras, ‘A Methodology for Determination and Definition of Key Performance Indicators for Smart Grids Development in Island Energy Systems’, *Energies*, vol. 12, no. 2, Art. no. 2, Jan. 2019, doi: 10.3390/en12020242.
[54] C. Corchero, J. Farré, L. Igualada, X. Pons, and M. Sanmarti, ‘Optimal energy management system for V2G chargers combined with PV and ESS in a real environment’.
[55] C. Heilmann and G. Friedl, ‘Factors influencing the economic success of grid-to-vehicle and vehicle-to-grid applications—A review and meta-analysis’, *Renewable and Sustainable Energy Reviews*, vol. 145, p. 111115, Jul. 2021, doi: 10.1016/j.rser.2021.111115.
[56] G. Graber, F. Lamberti, V. Calderaro, V. Galdi, and A. Piccolo, ‘Stochastic characterization of V2G parking areas for the provision of ancillary services’, in *2017 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT-Europe)*, Sep. 2017, pp. 1–6. doi: 10.1109/ISGTEurope.2017.8260256.
[57] U. C. Chukwu and S. M. Mahajan, ‘Real-Time Management of Power Systems With V2G Facility for Smart-Grid Applications’, *IEEE Transactions on Sustainable Energy*, vol. 5, no. 2, pp. 558–566, Apr. 2014, doi: 10.1109/TSTE.2013.2273314.
[58] L. P. Prencipe, J. Theresia van Essen, L. Caggiani, M. Ottomanelli, and G. Homem de Almeida Correia, ‘A mathematical programming model for optimal fleet management of electric car-sharing systems with Vehicle-to-Grid operations’, *Journal of Cleaner Production*, vol. 368, p. 133147, Sep. 2022, doi: 10.1016/j.jclepro.2022.133147.
[59] L. Jones, K. Lucas-Healey, and B. Sturmberg, ‘A report on business models’.
[60] Assured, ‘Fast and Smart Charging Solutions for Full Size Urban Heavy Duty Applications’, 2018. [Online]. Available: https://assured-project.eu/storage/files/assured-d25-final-requirement-and-kpi-tree-merged.pdf
[61] ‘Management of charging processes for electric vehicles | iit’. Accessed: Nov. 30, 2023. [Online]. Available: https://www.iit-berlin.de/publikation/management-of-charging-processes-for-electric-vehicles/
[62] ‘MOON ID Charger - para casa - Produto - MOON’. Accessed: Dec. 01, 2023. [Online]. Available: https://www.moon-power.pt/produto/para-casa/moon-id-charger
[63] UScale GmbH, ‘Public Charging Studie 2023’, 2023. [Online]. Available: https://uscale.digital/wp-content/uploads/2023/11/Pressehandout-Public-Charging-Studie-2023.pdf
[64] ‘Addressing EV Charger Communication Issues with Electric Vehicles’, Energy5. Accessed: Dec. 20, 2023. [Online]. Available: https://energy5.com/addressing-ev-charger-communication-issues-with-electric-vehicles

Questionnaire about the various actors

Questions about the EV

- Depending on vehicle sizes, battery and drivetrain characteristics:
  a) What are the current standards for bidirectional AC charging? (up to 22 kW on a Wallbox, ISO-15118-3 defines the hardware physical connection with the CCU, which is crucial for PLC, CAN communication between CCU and VCU)
     (i) Which plugs are common?
     (ii) Advantages of AC charging? (car owners do not have to pay extra costs)
     (iii) Disadvantages of AC charging?
     (iv) Impact on battery degradation?
  b) What are the current standards for bidirectional DC charging? (up to 350 kW on a fast charger, ISO-15118-3 defines the hardware physical connection CCU, which is crucial for PLC, CAN communication between CCU and VCU)
     (i) Which plugs are common? (CCS 1-2, CHAdeMO, etc. advantages, disadvantages)
     (ii) Advantages of DC charging?
     (iii) Disadvantages of DC charging? (car owners have to pay extra costs)
     (iv) Impact on battery degradation?
- A large number of EVs/charging stations in existing utility grid results in power-quality problems. The elements create harmonics that affect the distribution grid and can create power unbalances and voltage deviations.
  a) How can EVs contribute to grid stabilization to develop to develop beyond SotA standardization and hardware installation configurations for EVs, charging infrastructure and grid (V1G, V2G, V2X)?

Questions about charge points

- What are their most problematic restrictions for the most common charging technologies today?
  a) From technical point of view?
  b) From user point of view?
  c) From norms and regulations point of view?
- Charging technology to be followed up in XL-Connect.
  b) What are SotA solutions for large parking areas? (DC-microgrid -> possible use-case?)
  (iv) Position?
  (v) Charging characteristic / power?
  (vi) Number of charging connectors?
  (vii) Charging point installation configuration?
  c) Fast, high-power charging with reduction of energy and power adsorbed from grid using local power supplies connected to the microgrid (e.g., renewable energy sources, storage etc.).
  (viii) Are there approaches meanwhile already realized since the proposal creation?
  d) Grid support (frequency support, reactive power injection) using local power supplies connected to the microgrid

  (i) Are there similar solutions meanwhile already implemented since the proposal creation?

- Charge point operators: what is the current situation concerning the charge point management?
  b) Which protocols are used commonly to interface with the various stakeholders
- Concerning data and communication: The ISO 15118 standard (Road vehicles – Vehicle to grid communication interface) is the implementation standard.
  b) What communication protocols already exist, and which are still not defined?
  c) Higher-layer communication with the VCCU: via control pilot signals (e.g., PWM). Potentials to improve ISO-15118-20.
     Who can emulate bidirectional interaction between EV & EVSE-CCS using ISO15118-20 or other key enabling protocol for bidirectional charging?

Questions about smart charging providers

- Concerning energy management, pricing, grid and energy
  a) Currently, there are no established clear rules for the interaction between the distribution system and charging platforms. First the knowledge of the V2X ecosystem for the regulatory framework regarding provision of supplementary services with EV batteries and generally the participation in energy markets would be interesting.
     What are the differences throughout Europe?
  b) There exist many publications regarding Vehicle-to-Home, Vehicle-to-Building and Vehicle-to-Grid development.
     On which use cases XL-Connect will contribute (Digital twin model, norms and regulations, etc.)
     (i) Customer household?
     (ii) Commercial site/workplace?
     (iii) Bus depot?
     (iv) Virtual Power Plant?
  c) What is the needed hardware setup for each use-case?
     There is an interactive tool that might be helpful: https://sysarc.ffe.de/en
  d) Most common implemented revenue opportunities?
     (i) How are they mapped with regulations?
     (ii) How are they mapped with the various actor configurations?

Questions about grid and energy providers

- In order that we can structure data, we must know which data are needed.
  a) Geodata: what is included in geodata and how it is structured?
  b) EV and grid interaction data: what is included in this data and how it is structured?
  c) Grid fees data: what is included in this data and how it is structured?
  d) Grid-topology data: what is included in this data and how it is structured?
  e) Grid data (e.g., from CZ): what is included in this data and how it is structured?

f) V2G-data from Customers (e.g., from a small fleet at BMW): what is included in this data and how it is structured?
g) Primary data from energy operators: what is included in this data and how it is structured?

Questions about users

- Concerning accessibility, easy application, etc. ...
  a) Who has access to already aggregated user data, e.g., from earlier surveys for instance?
  b) How does the current communication strategy for users looks like?
  c) Where do users have objections?
  d) Where is potential to make (bidirectional) charging more attractive for users?
  e) Are gamification strategies meanwhile (since the proposal creation) present/spread?

(1) Current situation concerning user data protection.
  a) Liabilities?