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D7.2: Definition of the pilots, the validation methodology and metrics

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Abstract

The aim of this deliverable is to provide an overview of the validation methodology and metrics of the quantifiable aspects of the demo-sites. Various calculation methods were created in order to serve the goal of this paper. Those methods were created also with respect to changes developed over the time at the pilot sites.

Keyword list

KPI, Validation, Metrics, Use-Cases, Demo-Sites, HLUC, Flexibility

Executive summary

The shift towards a renewable energy production and supply requests new and demanding approaches. This is especially valid when it comes to the necessary flexibility of the electricity grids, as today's grids face great challenges regarding the fluctuating nature of renewables and, thus, need to be further developed and adapted. The aim of the pilots presented in this deliverable is to find and test such solutions at their test sites. These are located in Cyprus, Germany and Spain.

For a better understanding of the project settings, deliverable D7.2 which is the second deliverable of the FEVER Work Package 7 presents the different pilots. Further, the methodology to keep track of the advancements made and still needed is displayed.

Firstly, to give an idea of how the pilots are built up and in which locations they operate the settings of the demonstration sites are presented. Additionally, the actors and their roles embodied in each pilot are displayed as well as defined e.g., term prosumer. The setup of the infrastructures in which each pilot is situated and operates are explained.

The general description of the pilots is then followed by the changes done, as well as the achievements and progresses made in each pilot. Here, also the Spanish model to increase the willingness of potential customers to participate in the project is presented. Further, the planned measures in the future are named.

As the progresses made and planned need to me monitored, the validation methodology on the basis of High-Level Use Cases (HLUCs) is set and explained in section 3. A mapping of the HLUC testability on a pilot basis facilitated aligning the progress in the different pilots and the solution development, keeping track of the cooperation and communication between the different project partners. The different scenarios, as well as potential constraints and capabilities for the respective HLUC are displayed for each demo site (if applicable).

Furthermore, the UCs documented in previous work (i.e. D1.1 and D1.2) provided the basis for validation methodology. Key Performance Indicators (KPIs) are explained, providing formulas for calculation and mapping to the three pilot sites, revealing the processes to the demo site areas and giving an idea of how these achievements can be quantified. Use Case not relate to the tree pilot sites, but to the simulation environment (i.e. HLUCs 09-11) as well as their correspondent relevant KPIs were investigated within the framework of this document. Such information will be documented in the context of the deliverables of WP4. Consequently, only 12 out of 15 HLUCs are relevant for the pilot sites and will be, therefore, discussed.

The updated planning documented in this deliverable will provide the basis for the technical installations of the pilots, as well as the putting them into service phase. Upon completion, data feeds will enable the calculation of the presented KPIs during the validation period, on the basis of the work documented in this report.

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1 Introduction

FEVER project is a response to the call *LC-SC3-ES-1-2019, entitled "Flexible Energy Production, Demand and Storage-based Virtual Power Plants for Electricity Markets and Resilient DSO Operation"*, of the Horizon 2020 program. The FEVER's project objectives lie on three keys axes:

1. To implement flexibility measures and comprehensive flexibility aggregation, management and trading solutions, in order to provide electricity grid services, such as congestion management and overvoltage avoidance, at the distribution grid.

2. To implement enhanced monitoring and automated control of the distribution grid, by developing an innovative toolbox and implementing advanced technology that leverages flexibility form distributed resources towards providing ancillary services.

3. To implement market mechanisms and tools that support and incentivize flexibility services. These mechanisms concern different market structures and time-horizons (day-ahead and continuous trading of flexibility services, centralized and local/regional markets).

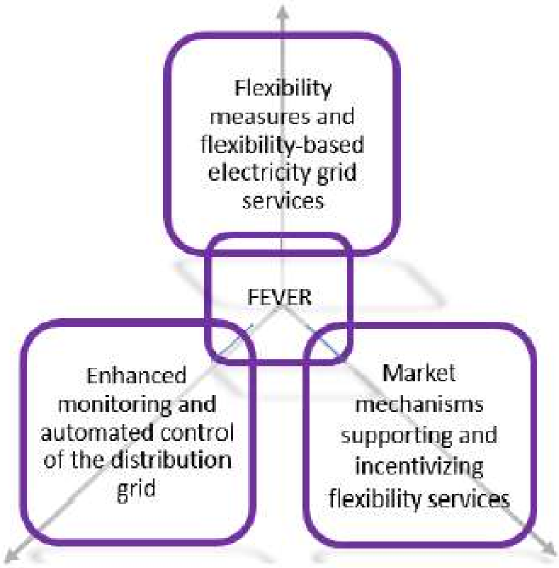

Figure 1: FEVER's high-level scope

In order to demonstrate the real-world applicability of the innovation concepts and to create a strong impact of the results, FEVER includes three real-world pilots in different countries, namely Cyprus, Germany and Spain. In addition to that, the project includes the design of a simulation testbed, to simulate the operation of electricity markets that incorporate novel flexibility-related services. In each demo activity, different specific objectives are set, overall contributing to the accomplishment of FEVER's high-level objectives.

To reach the project's objectives the pilots will become users of FEVER solutions, hence the specificities of each environment need to be defined as well as a methodology to measure and validate its impact.

1.1 Task 7.1

This deliverable is part of the work carried out within the context of T7.1 Definition of the pilots, the validation methodology and metrics. The task is dedicated to the definition of all the details related to the demonstration pilots of the project, the user engagement activities and metric to measure the impact of the project solutions, at individual technology level, at pilot level and at project level.

1.2 Deliverable 7.2 and its objectives

This deliverable focuses on the defining calculation methods, with which the pilots can validate the target and goals set at the beginning of the project with respect to current development, changes and add-ons being made at the pilot sites and demonstration cases in Germany, Spain and Cyprus. It describes how each pilot site intends to implement and demonstrate flexibility measures within the framework of this project.

The calculation methods developed for this deliverable will help assessing the results and optimise flexibility use on local systems.

The objective of this deliverable is to set and the course of action and validation, which will give guidelines for determining results at the pilot sites.

In addition, it will provide a Report presenting the details related to the demonstration pilots of the project in terms of scenarios and use cases to be demonstrated and validated as well as the KPIs for qualitative and quantitative assessment. This deliverable is related to Task 7.1

1.3 Outline of the deliverable

Chapter 2 presents general processes for user engagement that are relevant to FEVER. Further, more it describes the pilot sites and which changes occurred and need to be made in the course of time to accommodate new requirements. Chapter 3 summarises the High-Level Use Cases (HLUCs) and assigns the responsibilities of the different pilots. Further, the relevant constraints of each pilot and the testability are explained. Chapter 4 then presents the essential metrics in form of Key Performance Indicators (KPIs) with their calculation approaches. Finally, chapter 5 concludes the report.

1.4 How to read this document

Chapter 2 of this deliverable can be read on its own without further knowledge or information whilst chapters 3 and 4 are closely related to the previous work of the project i.e. deliverables requirements analysis *D1.1 Flexibility at the distribution grid: Reference usage scenarios for market and system operation services* [1] and *D1.2 Functional and operational requirements* [2]. There exist a close link to *D7.1 User engagement plan at pilot* [3](restricted to consortium), where the initial description of the pilots and the user engagement activities was presented.

2 Description of Demo-Sites

In comparison to D7.1, this chapter illustrates the current state and the changes made to the demo-sites of FEVER project in the course of time, as well as new requirements for each of the demo-sites. The demo-sites and their producers and consumers are all integrated in the Energy Management System (EMS) which is to be controlled by the Distribution System Operator (DSO) Toolbox to be developed by WP4. It is also connected to the trading platform.

2.1 Cyprus

2.1.1 Demonstration site setting

The campus of the University of Cyprus (UCY) is located in Cyprus, Nicosia. The facilities of UCY comprise of a number of non-residential buildings as well as DERs such as PVs and storage. The FOSS Research Centre for Sustainable Energy defines the energy strategy of the University (UCY) with the main aim to reach energy self-sufficiency. As a result, FOSS has a unique perspective of the energy needs of a variety of system actors including energy users as well as network operators. Furthermore, FOSS has control over the energy management system of campus buildings and can thus demonstrate the calculation and offering of flexibility.

Figure 2: UCY facilities map

UCY provides two principal options to demonstrate the flexibility leveraging capabilities depending on the different High-Level Use Cases (HLUC). First, load management of certain university buildings can be realised through the building energy management systems (BEMSs) and the central energy management system (EMS). The particular infrastructure will be exploited when flexibility requests are received from the market. In addition, the UCY will implement the converters-based assets and additional flexible loads which will operate in nanogrid level, in the grounds of the Photovoltaic Technology Laboratory (PVTL), to enhance load management scenarios and satisfy the relevant requirements of the rest of the HLUCs (e.g. reactive power compensation). More information on the demonstration of HLUCs in the Cypriot pilot can be found in Chapter 3.

2.1.2 Roles and actors

To clarify the parties contributing and involved in the Cypriot pilot, the roles and actors are presented in Table 1. Next to the assignment of roles to the different actors the different roles are explained in detail.

Table 1: Roles and Actors, Cyprus

Actors	Roles
Building's managers	Prosumer
DER owners	Prosumer
Microgrid Operator	Aggregator/Flexibility Service Provider
Nanogrid Operator	Aggregator/Flexibility Service Provider
Simulated	Flexibility Market Operator (FMO)
DER owners	Prosumer

- *Prosumer*: The owner of a source of flexibility, i.e. Distributed Energy Resources (DER). The business goal is the reduction of energy costs, without compromising its energy needs and comfort. The prosumers at the UCY pilot are represented by the BEMS which enables load flexibility capabilities of the various campus buildings and by PVTL users for DER assets which lie in the PVTL premises.
- *Aggregator/Flexibility Service Provider*: An aggregator of a series of flexibility sources. It offers flexibility related services to the flexibility market. His business goal is to ensure optimal operation of the flexibility assets and maximize profit. The role of the aggregator/flexibility service provider at the UCY pilot will be represented by the microgrid and nanogrid operator employing systems and applications within the FEVER project, such as the Microgrid Flexibility Management System (FMS).
- *Flexibility Market Operator*: It is the operator of the flexibility market. It receives demands and offers of flexibility related services and matches them. It isn't driven by any business goal apart from optimizing market operation. The Flexibility Trading Platform, developed within the project will be the tool used by the simulated actor representing the Flexibility Market Operator at the UCY pilot.

2.1.3 Prosumer and infrastructure

2.1.3.1 Campus microgrid

The campus of the UCY includes a number of buildings with uses ranging from offices, sport facilities, educational facilities, dormitories and even pure residential buildings that belong to the campus grid. The operator of each BEMS is representing a prosumer. These prosumers can participate in the flexibility trading during the UCY pilot. The buildings managed by the installed BEMS present different characteristics such as capacity, occupancy, size, number of floors, services etc. which result to a remarkable diversity among the load profiles of these buildings.

Control of the consumption of the electrical chillers is performed (indirectly) through the BEMSs which are accessed through the inEIS platform (a product of INEA). Currently 2 BEMSs (3 buildings) are directly connected and can be modified through the inEIS platform. The consumption of the chillers depends on the setting/choice of the cooling operation of each BEM (Automatic, Power Save, Normal, Power Boost). The available assets (BEMSs) of the UCY pilot, as seen in the inEIS platform, are shown in Figure 3.

The planned upgrade of the existing infrastructure will lead to 4 BEMSs (out of a total of 11 BEMSs) to be connected and controlled through the inEIS platform. Involved buildings connected to the 4 BEMSs will be equipped with energy valves which enable a more efficient and faster control of the electrical chillers. The use of energy valves will allow direct points of control and decreases the time response required for the feedback of the signal indicating the cooling operation of the corresponding building.

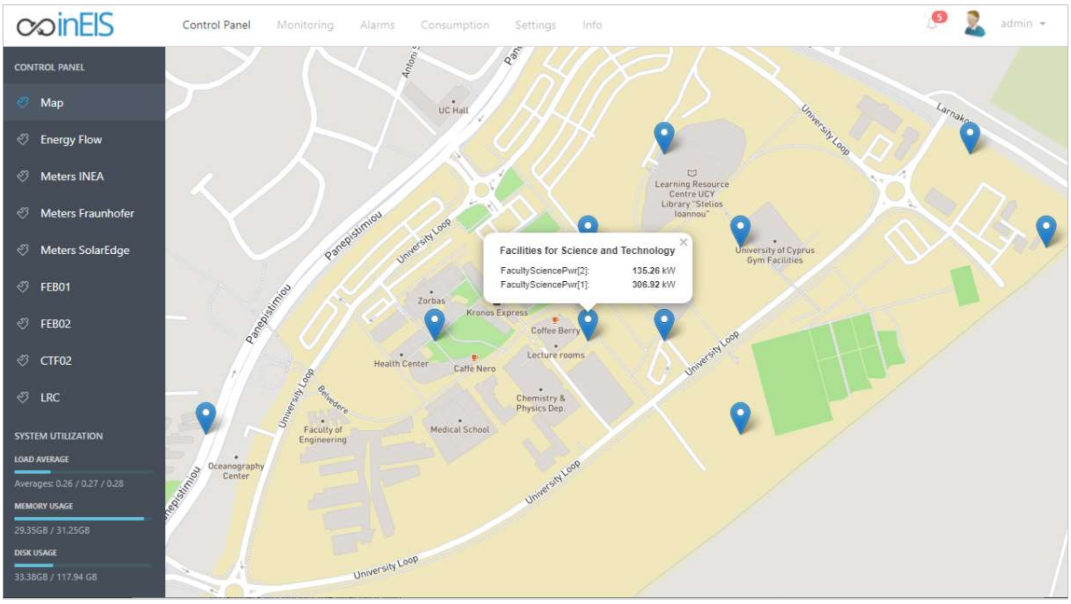

Figure 3: UCY building map in inEIS platform

Flexibility of the electrical chillers (single load) will be offered/traded/activated through the control of the energy valves of the cooling system of the buildings, thus their corresponding BEMSs which are connected to the inEIS platform. Although the energy valves and cooling operation settings of all university buildings have an impact on the consumption of the same electrical chillers, the flexibility which will be offered/traded/activated will be the change of electricity consumption corresponding to the control of the systems through the inEIS platform. The inEIS platform which serves as the UCY microgrid EMS contains integrated FEMS (Factory Energy Management Systems) and FSPA (Flexibility Service Provider Agent) building blocks which support the flexibility communication with FEVER FTP.

2.1.3.2 PVTL nanogrid

Additional infrastructure and flexible assets of the Cypriot pilot are located within the PVTL premises and are listed in Table 2. These assets are controlled by the campus nanogrid EMS and will be used to enhance the services offered by the Cypriot pilot.

Other non-controllable photovoltaic generators and non-controllable loads are located in the PVTL premises. Their operation, within the current status, cannot be controlled (no smart plugs, etc.) and can be monitored (indirectly) through the smart meters installed in the nanogrid.

A Remote Terminal Unit (RTU), along with microgrid control, is currently installed to act as the UCY campus nanogrid EMS. More information can be found in FEVER D2.1. The nanogrid EMS will communicate with the dedicated FSPA to transfer the adaptation potential to the FEVER's FTP.

Table 2: Infrastructure of PVTL nanogrid

Asset	Model
Smart Meters (2)	Schneider Electric PM8240
Real Time Hardware in Loop (Hil) Simulator	Typhoon HIL (HIL604)

Battery Energy Storage System – 2.5kW – 9.8kWh (Inverter)	SMA SBS25
Battery Energy Storage System – 2.5kW – 9.8kWh (Battery)	LG RESU10H
PV generator (2kWp) Inverter	Fronius Primo 3.0-1
PV generator (3kWp) Inverter	SMA SB3.0
AC/DC Electronic Load	Chroma 63804
A/C controllers	Intesis IS-IR-WIFI-1 universal A/C controller
Dimmers	(pending)

2.1.4 Customer engagement in the Cypriot pilot

The business model and timeline of the customer engagement plan were presented in D7.1 [4] and was divided in the following three stages:

- INVOLVE: understand who you are talking to, start by simple involvement and be ready for hesitation and questions
- ENGAGE: take onboard through incentives
- EVOLVE: evolve the relationship by collecting feedbacks

The up-to date progress of the engagement plan is as follows.

The particular nature of the Cyprus pilot which in its entirety is located within the university campus does not include multiple customers. The technical services of the university are responsible for the operation of all participating buildings. The Involved and Engage phases of the engagement plan have been realized through biweekly sessions with the technical services in form of interviews. The requirements and needs of the BEMSs with respect to the HLUCs of the project were discussed and specified. Material was shared to promote the concepts of the project and facilitate cooperation and advance relationships.

Group meetings were held with the users of PVTL (Photvoltaic Technology Laboratory), where the nanogrid EMS controls the operation of certain DERs. These meetings enabled the coordination of flexible DERs and involved infrastructure and allowed the alignment of technical requirements for the lab operation.

Currently, the engagement stage has been completed and will be succeeded by the integration and validation phase of the pilot.

2.2 Spain

2.2.1 Demonstration site setting

The Spanish pilot will be operated by Estabanell Distrbution and Mercator and aims to demonstrate how the activation of aggregated local flexibility can be used in ancillary services, as well as enhance the observability and controllability of the distribution grid in light of the ever-expanding penetration of distributed generation. In particular, the pilot will demonstrate the feasibility and impact of blending complementary flexibility technologies with different availability and dynamics, as well as the capability of controlling islanding grid mode. Flexibility in the pilot will come in the form of flexible storage of electricity in stationary and EV batteries, as well as from industrial clients load capacities. The main service that aggregated flexibility will provide to the DSO is support to congestion management. Additionally, special features of the power electronic devices (PEDs) that manage batteries' arrays will be leveraged towards the provision of ancillary services such as voltage control, reactive power control, and distribution lines harmonic compensation, phase balancing and losses reduction. Positive impact is expected to be observable at both substation and consumer level.

Figure 4: Electrical infrastructure of EyPESA

The pilot will take place entirely in the grid managed by Estabanell Distribució's corporate company Estabanell y Pahisa SA (EyPESA). EyPESA is a DSO based in Catalonia. Its electrical grid was initially built more than 100 years ago to supply electricity to the textile industry and was later expanded to supply electricity to other towns and end users. EyPESA has more than 120 km of 40 kV sub-transmission network and more than 1000 km of medium and low voltage network passing through 31 towns. In terms of the amount of the supplied energy and the number of connected costumers, the most important towns are Granollers, La Garriga and Tona. In its electrical grid, EyPESA is managing 5 micro hydroelectric power plants, has more than 1 MW of installed PV capacity with different sizes and generation capabilities of individual plants, and is integrating more and more Electric Vehicle (EV) charging points. The 29% of the EyPESA market is concentrated in urban area (Granollers), 24% is semi-urban areas, 22% in rural areas, and 25% in dispersed rural areas. Over the whole coverage area, 63% of contracted power is provided to residential customers. As for industrial and commercial demand, 73% of the demand is in urban and semi-urban areas. It is in this infrastructure that the industrial prosumers are located, as it will be explained in further details in the following chapter 2.2.3. These prosumers are clients of both EyPESA and Mercator, the energy retailer, that has a client portfolio of around 50000 costumers, with a marketed energy of 331 GWh in 2020.

The section of the pilot dedicated to validate V2G exchanges will be carried out within this grid. More specifically, using two of Estabanell Distribució electrical cars which will be connected to the grid from two residential smart chargers in the company's internal parking.

Finally, the last part of the pilot aims at extracting flexibility services from batteries and PEDs connected to Estabanell Distribució grid. This equipment is located in the Osona region in Catalonia (Spain). The area is considered a concentrated rural area with 2216 inhabitants. The whole pilot area has a distribution network at 5 kV with 20 serving substations, bringing the voltage to the standard low levels of 230 V or 400 V.

Within this area, in a village called L'Esquirol, the existing battery setup composed of 58 kWh battery set (30 kWh lithium + 28 kWh lead-acid) and 75 kVA PED will be used. These are connected to a LV grid through 3 switchgears that can reconfigure the electrical scheme so to active such battery set. A similar set of an IDPR and batteries is located in the other village that is part of FEVER's pilot, Vallfogona, located north of L'Esquirol.

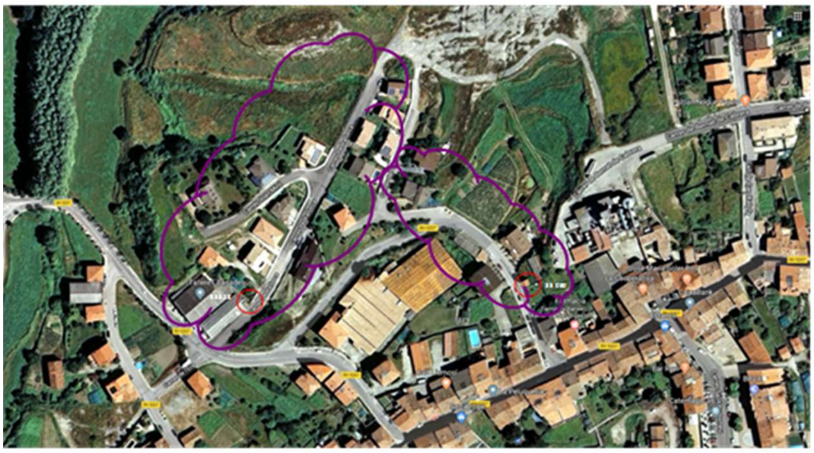

Figure 5: Aerial view of Estabanell Distribució grid in the Osona region

2.2.2 Roles and actors

To clarify the parties contributing and involved in the Spanish pilot, the roles and actors are presented in Table 3.

Table 3: Roles and Players, Spain

Actors	Roles
Estabanell Distribució	DSO
Estabanell Distribució	V2G prosumer
Estabanell Distribució	Flexibility Service Provider
Mercator	FMO
Mercator	Aggregator
Industrial Client	Industrial prosumer

Estabanell Distribució is the entity in charge of managing the distribution grid and its operation in the municipalities of Granollers, Tona and St. Pau de Segúries. For the scope of this project it will assume the roles of the DSO, V2G Prosumer and Flexibility Service Provider.

Mercator is the commercial entity when it comes to the actual sales and electricity contracts for the Estabanell y Pahisa SA. For this reason, Mercator will be both the FMO and the Flexibility Aggregator.

Finally, a crucial role will be played by Industrial Clients which provide flexibility services to the DSO, making some of their assets available for load management.

2.2.3 Prosumers and infrastructure

The target clients are industrial players with relevant loads, regardless of the specific industry they participate in. In order to be a fit for this project they must satisfy two basic requirements:

1. They must be clients of both Estabanell Distribució and Mercator to be able to assess the effect of the flexibility measures that will be put in place on our distribution grid.
2. They must have contracts for more than 100kW. This threshold is based on technical considerations regarding the minimum load that allows to extract sufficient flexibility services while not impacting the client's processes. In facilities with more than 100kW of connected power we should be able to modulate loads without having to stop any critical process.

With these two requirements in mind, a list of the industrial clients has been made identifying 49 possible clients. The table below is an example of some of the clients in this list:

Table 4: Example list of eligible customers

#	Innovativeness (0-5)	Max Power (kW)	Consumption (kWh/year)	Activity Code (CNAE)	Activity Description
1	5	1.000	4.641.087,6	2592	Manufacture of light metal containers and packaging
2	3	700	2.109.966,0	5510	Hotels and similar accommodation
3	4	650	1.128.372,0	1061	Manufacture of grain mill products
4	1	500	1.348.323,6	1621	Manufacture of veneers and wooden boards
5	3	460	724.964,4	2399	Manufacture of other non-metallic mineral products

The 49 selected industrial players have been categorized according to their max power withdrawal from the grid, their annual consumption, their CNAE (Clasificación Nacional de Actividades Económicas – National Classification of Economic Activities) and their degree of innovativeness. Initially, the idea was to target only prosumers belonging to the power-to-cold industry but given some technical limitation like minimum power consumption of 100kW in the project definition we have expanded our scope to include all industries.

This latter classification is a purely indicative index that has been deducted via direct consultation with sales agents of FEVER beneficiary Mercator (MER) that has knowledge of each single client and their organizations. Clients with innovativeness score of 0 are the least innovative, the ones most likely to stick to their core business, routine activities, and less incline to take any risk in other projects. Clients with innovativeness scores of 5 instead are the most innovative, they usually have resources dedicated to innovation inside the company and show interest in participating in projects even when proposed from third parties.

The goal is to acquire 5 of the 49 selected parties to conduct the final pilot. This number is derived by the limited number of FEMS (Factory Energy Management Systems) that can be financed through the project budget and that are necessary to monitor, control and act upon factories' assets.

There are already three clients that have agreed and signed the participation in the project, and therefore will be part of the pilot. These are an industry providing metallurgical products and services (laser cut, plasma cutting, oxyfuel, cut profiles to size, bias cut, sheet metal cutting, etc.), a sports and health centre with climatization, indoor swimming pool, restaurant and parking among other facilities, and finally a manufacturer of high-tech surfaces for kitchens (strips, panels, countertops, baseboards, cornices, and a whole series of elaborate products for the kitchen such as cabinets, doors, kit modules and edged boards). The maximum power in these clients' contracts are 350 kW, 250 kW and 100 kW. Their industrial processes and capacities are now being analysed.

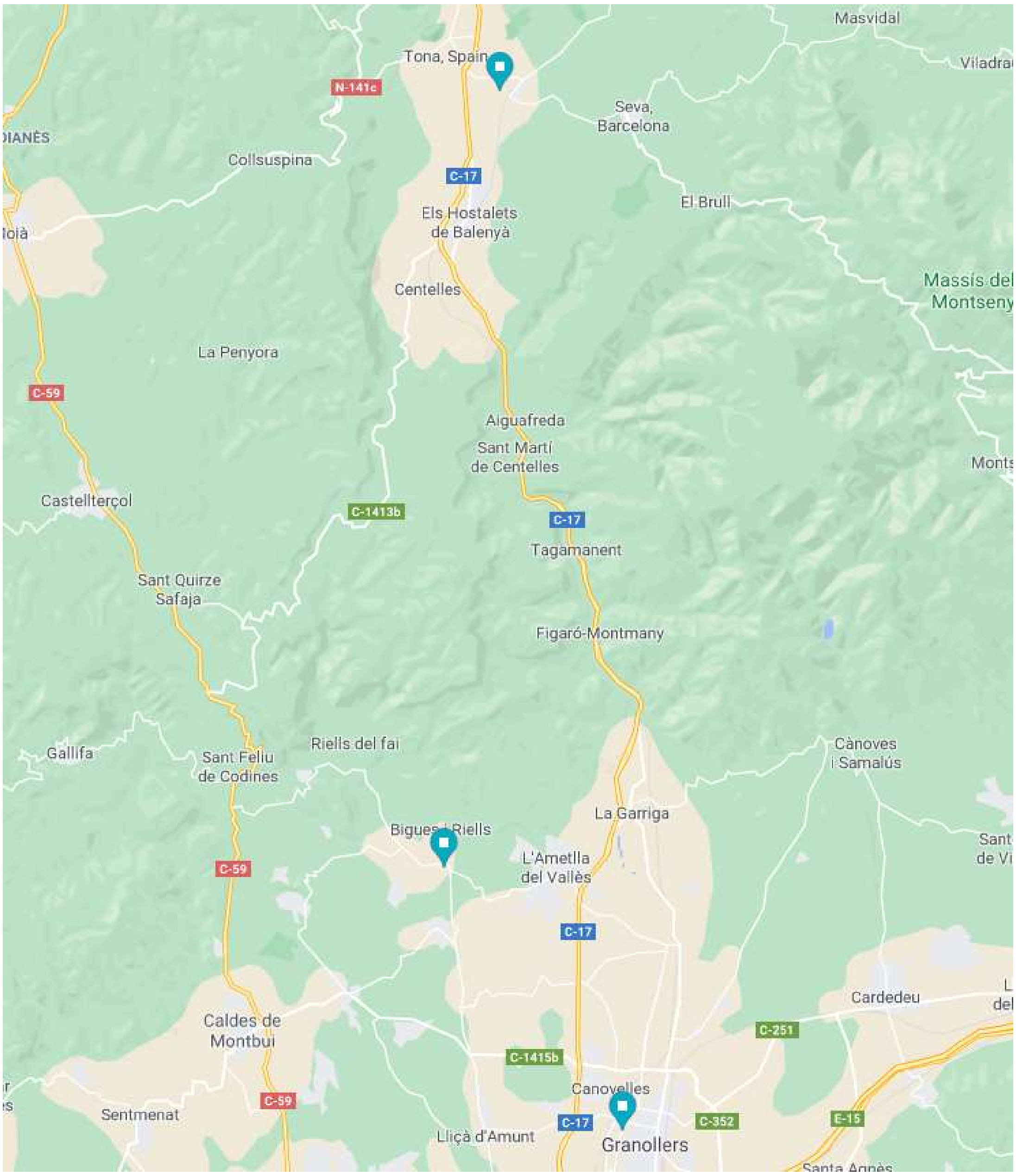

Figure 6: In blue, location of the three confirmed industrial clients

2.2.4 Business model applicable in the Spanish pilot

In this paragraph the business model used to capture the industrial prosumers' interest in participating in the Spanish pilot is explained. Below, each of the section of the Business Model Canvas is briefly analysed.

Table 5: Business Model Canvas template

<table>
<tr><td rowspan="2">Key Partners</td><td>Key Activities</td><td rowspan="2">Value Proposition</td><td>Customer Relationship</td><td rowspan="2">Customer Segments</td></tr>
<tr><td>Key Resources</td><td>Channels</td></tr>
<tr><td colspan="3">Cost Structure</td><td colspan="2">Revenue Structure</td></tr>
</table>

A keystone of the business model is the Value Proposition that we bring for our potential participants. It will be centered on three areas, namely SOCIAL, TECHNICAL and ECONOMIC.

Regarding the social area, there are several benefits for the participants. From a reputational perspective, taking part in this project shows active participation in the energy transition toward the exploitation of renewable resources. It shows the innovativeness of a company and can help attracting other partnerships. Being involved in a pilot project allows prosumers to get a clearer idea on the current energy state of play and on the outlook from a European perspective, anticipate possible changes and better comprehend them. Finally, the project will establish a stakeholder community of engaged partners. Being part of such a community, opens up opportunities for other collaborations.

From the technological point of view, the benefit of participating in this project lays in the necessary action that need to be done on prosumers' assets. In particular, the necessity to map and control such assets would expose the prosumers' energy situation, allowing to optimize it and saving costs.

The economic incentive is present in the form of lower energy bill due to optimization of existing assets which would translate in higher efficiency and reduction of peak loads. As a last resource, we would also propose monetary incentives, either directly based on some participation index to be defined or indirect as energy bill discounts.

The user segment that will be of interest would fulfill the following categories:

- Any industrial sector
- Able to provide flexibility services
- Contracted power higher than 100kW
- Connected to Estabanell Distribució grid
- Customers of Mercator

Once the specific clients belonging to this segment have been identified, we plan to establish a connection via different channels:

- Existing commercial relations: these will be the cornerstone that will permit to get in contact in the first place
- Email: because of their simplicity of use and practicality when in need of sharing material this will be the main channel for official periodic communications
- Face-to-face interviews: establishing a direct connection with the customer would help in creating the feeling of engagement that we aim at; in addition, these would be the best solutions for gathering costumers' ideas and co-create
- Group meetings: especially important to create the feeling of community and to get to know the different clients' perspectives
- Video conferences: a practical alternative to face-to-face interviews, especially useful considering the social distancing measures in place due to the COVID-19 pandemic

Through these channels we aim at building participant relationships that persist after the end of the pilot. Some important factors for creating and nurturing these relationships are listed below:

- Existing commercial relations with Mercator's commercial agents
- Co-creation events
- Creation of stakeholders group and group events

In order to carry on this engagement plan, it will be necessary to rely on a few key partners that can contribute in different ways to the success of the project:

- Associations: they can help as testimony of the reliability of the project, both from a purely technical perspective and from a social/environmental one.
- Technological partners: will be crucial in creating a documentation that can be shared with the client and that could explain our solution from a technical perspective. They will also be asked to help clarifying eventual users' doubts on the functionality of the technology.
- SWW: Task leaders, previous experience in similar projects involving installation at prosumer premises
- BAUM: Partner involved in dissemination and communication, will help with setting up the strategy and as consultant maintaining relationships with clients

Another section of the business model canvas is the one dedicated to key activities. Below a list of the most important activities that will have to be carried out during the whole duration of the project, in the effort of engaging, involving and evolving the relations with the clients:

- Create documentation, digital and physical
- Reaching out to external associations
- Conduct interviews
- Organize group meeting
- Organize periodic events or workshops in order to gather feedbacks
- Organize visits at user sites

All these efforts will be performed by the key resources dedicated to the project. The biggest part will be played by human resources internal to EST and MER, some will be directly assigned to the project while other will be consulted sporadically only when needed.

- Human resources:
    - Innovation department
    - Marketing and communication department
    - Sales department
    - Business development department

From an economic perspective, the cost structure will be represented mostly by the following items:

- Human resources
- Travel expenses
- Eventual purchase of INEA's FEMS
- External resources if needed (user engagement, energy audits)

Defining the resource structure is not simple challenge now, given that the flexibility market does not exist yet and its specific functioning will be defined later on in the project. Having said this, following a few possible indirect sources of revenue.

- Short term
    - prosumer fidelity
- Long term
    - MER: Engagement of future flexibility sources to be exploited when the flex market will be regulated
    - EST: avoided network upgrade costs

Given the importance of clarifying in detail the strategy that we setup in order to capture users' interest, a more detailed description of the different stages of the user engagement plan with references to a possible time schedule are outlined.

In order to capture the users' interest and availability, a plan of action divided in three successive phases has been developed, each characterized by its own peculiarities and challenges as illustrated in the following image.

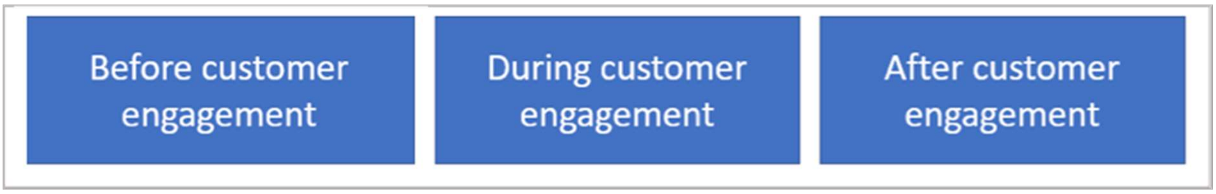

Figure 7: Phase of customer engagement

First, there is the current preparation phase, namely *Before User Engagement*.

In this phase, the focus is on fine-tuning the successive phases, making assumptions and evaluating which strategy would be the most effective. In particular, the following steps are being defined:

- User segmentation
- Engagement/communication strategy
- Users' values
- Timeline and interactions
- KPIs
- Allocated resources

For what regards strategies definition, here below are mentioned the three most relevant that have been selected from the BRIDGE literature [2]:

- LISTEN AND CO-CREATE
  Involve the stakeholders in values and barriers identification, understand their personal views in order to come up with a co-designed solution and create deeper bond.
- COLLECTIVE ACTION
  Creation of a long-term group of stakeholders with the aim to involve authorities and create the base for collaboration on various projects.
- COMMUNICATION
  Put emphasis on the communication side using simple and visual communication tools, manage clients' expectations, and build trust.

The last point focuses on whether there is a need of a local external consulting company (not member of the consortium) helping to reach more effectively the target users. Given the amount of work that we forecast will be needed to maintain the relations with the users (organizing workshops, issuing periodic newsletters, answering to any customer question, etc.) we are evaluating if it will be necessary to subcontract a third external company to carry on a few of these tasks.

2.3 Germany

SWW Wunsiedel GmbH and SWH Stadtwerk Hassfurt GmbH are located in Franconia, in the northern part of Bavaria. The distance in between the two cities is about 150 km and the population in the area counts up to a number of 100.000. The region has a rural character which includes a high volume and density of RES. The RES distribution counts for about 1.000 PV sites of all sizes, several windparks, some hundred heat pumps, battery systems, hydrogen applications (Power-to-Gas, FuelCell) and EV charging systems. But also „empty spaces" to be covered and bridged by the FEVER system. The consumer/prosumer population covers all types from industry, SME, professional RES sites, farms, multifamily residences with common installations and single homes.

The basic idea of the German pilot is to build a flexibility and sector coupling energy market that spans from Wunsiedel in the east over 150 km to Hassfurt in the west, having between 3 and 5 pillars in local energy communities in the space between. All the achievements of the partners from the past shall be shared, tested and applied vice versa, first with the two DSOs and then with the energy communities. After this phase the combined solution shall be offered to 5 municipalities with a headcount of about 300.000 inhabitants to be adopted.

The general target is to technically include all types of buildings and implement technology to provide multi-layer flexibility (consumer/ building/DSO). This also covers PV, wind turbines, CHPs and batteries, EV charging, Power-to-Gas/Hydrogen applications, urban and rural, hot water heaters, heat pumps, thermal energy storage and district heating. Based on the technical integration the business goal is to create and evaluate models for flexibility trading and C2C trading.

This all-inclusive regional flexibility management will be based on existing flexibility and FEVER infrastructure and rules, with all data collected and stored securely, a full integration with hardware and service providers and a complete integration with all FEVER platforms of the project

2.3.1 Demonstration site setting

During the project changes to the initial plans of using the budget occurred. Therefore, the German pilot will use the persisting infrastructure and will shift some of the budget to erect a High-Level Quality Management instead to, especially, support the performing of HLUC04. The suggested re-allocation of the budget is presented in Table 6 below.

Table 6: Option of different use of budget for purchasing supportive equipment for HLUC01, HLUC04, HLUC13, HLUC14

		SWW	
Initial		**52**	
Type of material	**number**	**cost (k €)**	**explanation**
PQ-measurement	14	28	8 HLUC 1+4 Schönbrunn, 6 HLUC 12+13+14 Breitenbrunn
Communication HW	14	4	8 HLUC 1+4 Schönbrunn, 6 HLUC 12+13+14 Breitenbrunn
Communication ops		3	
Software Licence	1	9	PQ-Measurement
Install. Material		5	
Balancing area ops		3	Simulation of Energy Community in Wunsiedel
		52	
		SWH	
	initial	50	
Type of material	**number**	**cost (k €)**	**explanation**
PQ-measurement	6	12	6 HLUC 12+13+14 SWH Subgrid
Communication HW	6	2	6 HLUC 12+13+14 SWH Subgrid
Communication ops		1	
Software Licence	1	9	PQ-Measurement
Install. Material		3	
Balancing area ops		3	Simulation of Energy Community in Hassfurt
Connector box		3	
		33	
Shiftable		17	

Es-geht!			
Initial		**32.8**	
Type of material	**number**	**cost (k €)**	**explanation**
Power Factory Lic.	1	15	
Laptop	1	2.5	done
Software Licence	1	2	Energy Management EC (shiftable in case)
Meters		5	Energy Management EC (shiftable in case)
Non-EMS		5	Energy Management EC (shiftable in case)
Communic. Meters		3.3	Energy Management EC (shiftable in case)
		32.8	
(shiftable in case)		15	

Figure 8: Flexibridge between Wunsiedel und Haßfurt

The *Flexibridge*, is in the process of being created and will be conducted by an external balancing service provider. The aim of the implementation is to build a bridge between SWW and SWH which are apart from each other over more than 100 km (shown in Figure 8) and are additionally separated by a grid which is operated by Bayernwerk. Thus, the two grids cannot be connected physically, and a balancing approach is needed which is provided by the Flexibridge to enable the trading of energy flexibility between the two balancing groups.

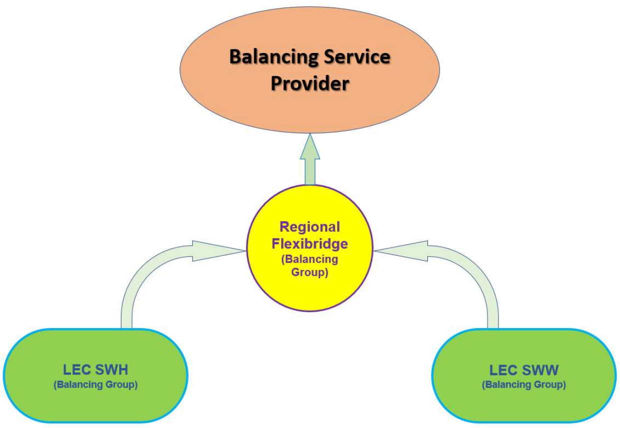

Figure 9: Functional implementation of the Flexibridge

For this purpose and also due to current regulatory frameworks, Local Energy Communities (LECs) within each pilot area (i.e. SWW, SWH) will be represented by a balancing group, making balancing between SWW and SWH possible based on the existing regulatory balancing framework. This is necessary, as the regulatory framework in Germany does not allow LECs, yet. Therefore, the balancing groups serve as “place-keepers” until the regulations make an establishment of LECs possible.

SWH and SWW are connected via a third balancing group which acts as the Flexibridge. The bridge consists of balancing between the two separated LECs, as they cannot be physically connected. The Flexibridge will be managed by a Balancing Service Provider (BSP). Figure 9 shows the three balancing groups necessary to build the Flexibridge within the current regulatory framework.

2.3.2 Roles and actors

To clarify the parties contributing and involved in the German pilot, the roles and actors are presented in Table 7. Next to the assignment of roles to the different actors the prosumers are defined as specific customers and assets part of the German pilot.

Table 7: Roles and Actors, Germany

Actors	Roles
SWW and SWH	DSO
SWW and SWH	Retailer
SWW and SWH	Flexibility Service Provider
To be determined	FMO
SWW and SWH	Aggregator
Industrial and Domestic Customers of SWW/SWH	Prosumer
LEC	Local Energy Community(ies) with individual balancing group
$F_{(x)}$-Energy	Balancing Service Provider

SWW and SWH are DSOs as well as energy retailers and flexibility aggregators in their region. They are forming LECs within an individual balancing group, each.

Industrial and Domestic customers play an important role as prosumers in this pilot. Whereas the role of an FMO still needs to be determined.

2.3.3 Prosumers and infrastructure

This section presents the list prosumers and infrastructure of the German pilot. They are divided into the different belonging to SWH or SWW. Each prosumer and infrastructure presented is part of the respective balancing groups, also presented as LECs SWW and SWH in Figure 9.

2.3.3.1 SWH

The following customers are recruited:

- 5 Industrial Customers
    - Jam-producing factory 40-60 kW

- H_2 CHP of a malt roastery 140 kW
- Water works facility with PV and storage electrical.2.1 MW electrical, 60% von 1.6 MW battery
- Biogas plant (CHP) 400 kW electrical production
- Elevated water storage tank with pumps (6 pumps à 2.2 kW; total 13.2 kw)

- 30 Smart plugs (domestic users)

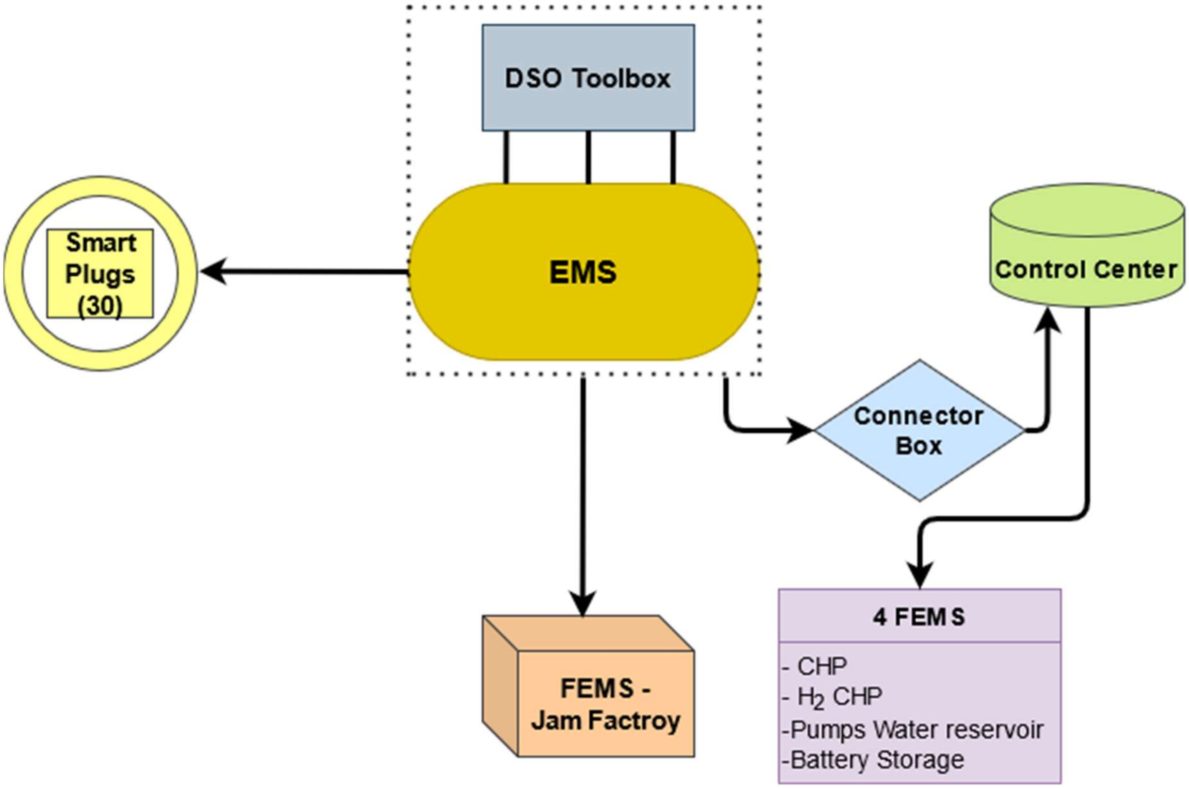

Figure 10: Demo Set for German Pilot SWH Site

After being installed in SWH, the flexibility aggregation system which is equivalent to the Energy Management System (EMS) in Figure 12, shall communicate with four of the five FEMS using a connector box. This connector box acts as an interface between the flexibility aggregation system and the control center software to which the 4 FEMS are already connected to. It thus saves four communication applications by INEA, as the four FEMS attached to the Control Center can be managed in a bundled manner (cf. Figure 10).

2.3.3.2 SWW

The following customers are recruited and displayed in Figure 11:

- More than 10 "Industrial Customers" (see Table 8 for capacities):
  - Wastewater treatment plant
  - Water storage facility (2x)
  - Brewery
  - Trading company with battery, PV and charging units
  - Medical spa
  - Office and HQ Buildings with battery, PV and CHP (6x)
  - Carpenter with drying chamber
  - Biogas plant (2x)
  - Large CHP with district heating (2x)
  - Medium size CHP with district heating
  - SWW pellets production
  - SWW woodchips CHP and natural gas CHP

- Domestic users
- Electrical Storage Heating Systems (domestic users) (Direct control)
- 50 Smart Plugs (domestic users)
- 6 Charging Stations (SWW and public users)

Table 8: "Industrial Customers" (FEMS) in the German pilot at SWW site

Customer	Capacity
Wastewater treatment plant	2x 30 kW CHP + 80 kW PV (limited to 100 kW, due to small capacity of main cable)
Water storage facility (2x)	4.12 kW + 0.06 kW
Brewery	16.2 kW
Trading company with battery, PV and charging units	61 kWp + 47 kWh electrical storage
Medical spa	26 kW
Office and HQ Buildings with battery, PV and CHP (6x)	101.6 kW PV + 5.5 kW (CHP)
Carpenter with drying chamber	40 kW
Biogas plants (2x)	180 kW + 250 kW
Large CHP with district heating (2x)	80 kWp PV + 2x 190 kW electrical production
Medium size CHP with district heating	50 kW
SWW pellets production	287 kWp PV
SWW woodchips CHP and natural gas CHP	900 kW electric + 80 kWp PV + 60 kW

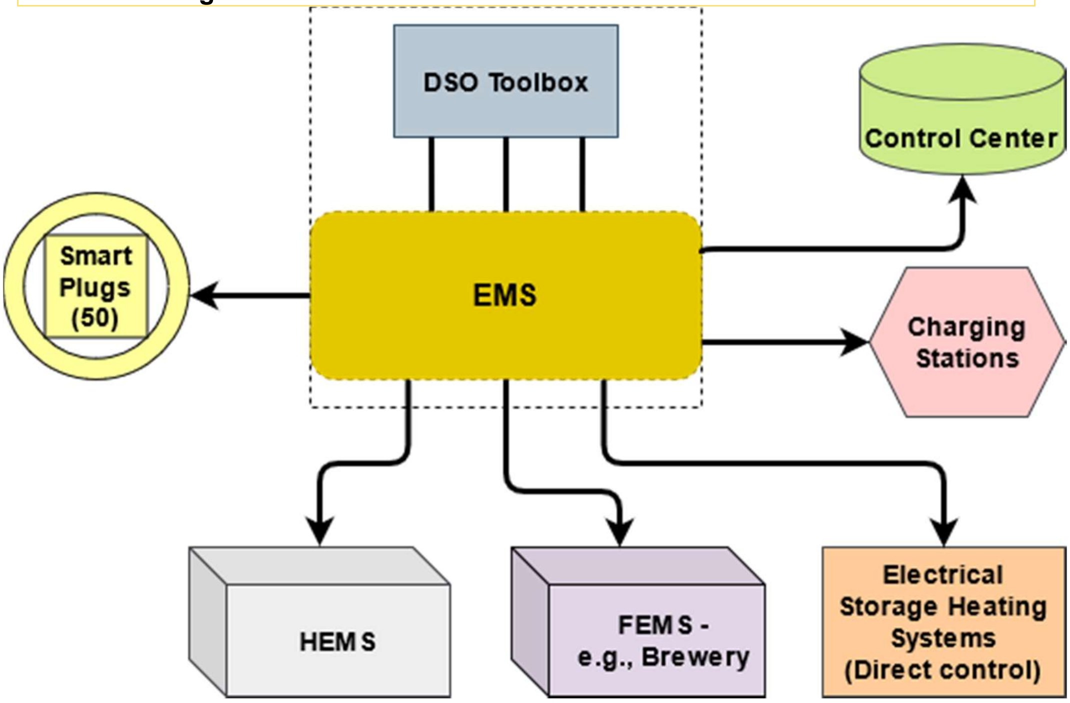

Figure 11: Demo Set for German Pilot SWW Site

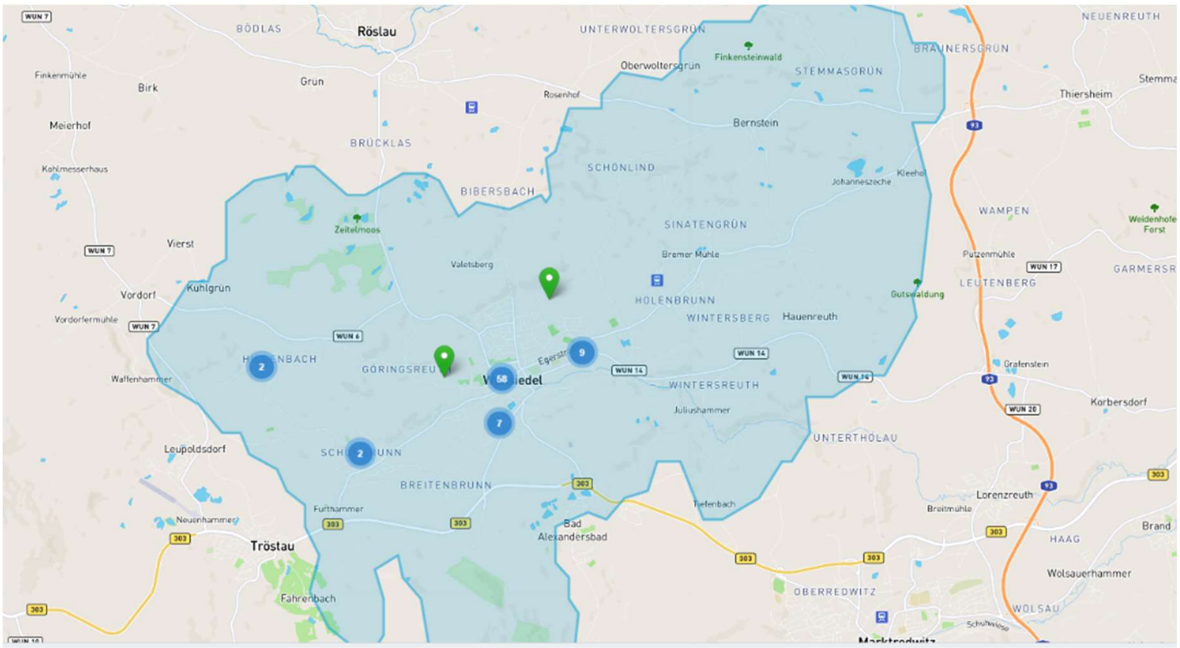

Figure 12: Map of SWW Wunsiedel GmbH with the potential of residential and commercial customers for FEVER

3 Use Cases and Scenarios

Use Cases (UCs) are an essential part of a proper analysis and definition methodology which is needed to successfully identify and understand the technical requirements of the development and integration of new functionalities in engineering systems. The approach using UCs has been proven especially useful when software-based and hardware-based advances are combined. UCs define the necessary actions performed by a system that will provide an observable impact which should be of interest for certain stakeholders. Furthermore, they ensure the understanding of the functionality for all stakeholders. This ensures that coordination and collaboration, as well as communication between the different participants in the system are secured. [1]

The following High-level Use Cases (HLUCs) were developed in the context of WP1 (see [1]) and describe the general idea of the functionalities related to flexibility activation, by defining the actors and their respective roles while sketching their responsibilities. They pose the basis for lower-level use cases which are then concluded from the former, such as Primary (PUC) and Secondary Use Cases (SUC) (see [2]) and the means to validate the impact of specific processes (cf. 4 Validation Methodology). The section aims to identify the specific scenarios to be tested by the pilots, hence their possible constraints and capabilities are presented. For a basic understanding of the HLUCs the short narrative section from D1.1 is included whereas the simulation cases HLUCs 09-11 and the relevant KPIs are in the context of WP4 and explained there.

3.1 Pilot Scenarios

3.1.1 HLUC 01: Advanced network congestion management considering DER & grid flexibility (seasonal, day-ahead, etc.)

3.1.1.1 Overview

This use case has the objective of preventing congestion issues in the distribution grid by exploiting network flexibility, i.e. reconfiguration of the network topology in the problematic grid area, and DER flexibility, provided by dispatchable DERs located at distribution level. Congestion management can be considered in different timeframes, i.e. real-time operation, operational planning, and long-term planning. DER flexibility remuneration can be realized via bilateral contracts and/or flexibility markets operated by a third party.

3.1.1.2 Scenarios

3.1.1.2.1 Cyprus

HLUC01 will not be demonstrated in the Cypriot pilot.

3.1.1.2.2 Germany

According to par. 15 of the German regulation on electricity feed-in to and consumption from electricity supply grids local utility companies have to prepare a prediction plan. [5] This is relevant for the piloting, as there are, thus, legislative frameworks regarding the feed-in management which need to be implemented by the DSOs.

The testability for the German pilot will be shown as the time taken to activate “x” amount of flexibility through local demand reduction measures.

We expect no congestions due to proper physical expansion and upgrade of grids and a substantial electrical storage unit.

3.1.1.2.3 Spain

This use case will be tested in the Spanish pilot by using both the switchgears to reconfigure the network, and the DER assets to prevent congestion issues in the distribution grid.

In this pilot, grid reconfiguration entails the proper scheduling of the switchgear’s operational status in order to modify the network power flows such that the loading of the problematic area is limited. The dispatch of the grid reconfiguration is ordered through the SCADA system (DS- SCADA) and at the time established in the schedule.

In case that grid reconfiguration is not adequate to solve the congestion issue, the flexibility offered by the distributed dispatchable assets (consumption, production or storage units) affecting the operation of the problematic area, such as the loads of industrial clients, are exploited.

As assumed in D1.1, the flexibility offered by DER assets and the one requested by DSOs will be correlated with their location in the distribution grid since congestion issues have local and not systemic characteristics. Moreover, the network and consumption data requested by the CEPA for performing power flow analysis of the distribution will be available. The granularity and updating interval of the data as well as the accuracy/resolution of the generation and demand, will be crucial for the quality of the forecast.

This use case will be tested in a virtual grid, where all the assets will be represented identically as they are in the real grid. This is because the location of the several assets involved in the pilot are not close to each other, and therefore testing actions in the real grid would not have the expected impact in terms of congestion issues. The virtual grid then will represent the exact same assets, but all connected to each other for more direct impact. No constrains are expected in the pilot to test this scenario.

3.1.2 HLUC 02: Voltage compensation via reactive power procurement

3.1.2.1 Overview

This use case has the objective of preventing voltage excursions in the distribution grid by exploiting battery storage reactive power flexibility located at distribution level. Momentary voltage issues are identified and corrected in the close to-real-time frame. DER flexibility remuneration can be realized via bilateral contracts and/or flexibility markets operated by a third party.

3.1.2.2 Scenarios

3.1.2.2.1 Cyprus

Assets of the Campus nanogrid (PVTL nanogrid) will be used to showcase the use of DER flexibility for ancillary services, specifically flexibility of reactive power for voltage compensation. The nanogrid's reactive power can be changed by controlling inverters, battery inverters or PV inverters. The battery's inverter (SMA Sunny Boy Storage 2.5) and the PV generators' inverters (SMA SB3.0 and Fronius Primo 3.0-1) can be used to provide reactive power flexibility.

The Cyprus pilot does not include the participation of the DSO; thus, the need and activation of reactive power flexibility will be determined based on scenarios. The objective is to illustrate the aggregation of DERs' flexibility of a microgrid for reactive power procurement.

3.1.2.2.2 Germany

Due to the new demands posed by Redispatch 2.0, the local DSO will take upon the responsibility for voltage compensation from October 2021 on. This task has to be fulfilled by direct steering of generation units which have an installed capacity of 100 kW or more.

3.1.2.2.3 Spain

This use case will be tested in the Spanish pilot, with the exact location to be defined. This will be one or more of the following three: L'Esquirol, Vallfogona or Estabanell headquarters with the V2G.

To make a suitable use of reactive power control capability higher observability of the network will be provided in order to detect and smooth voltage variations. In this respect, the power electronics components of the battery array together with other monitoring devices and sensors will be used also for acquiring field data. Collection of data will be done by Estabanell, through its SCADA infrastructure (sensors, analyzers, PED, etc.).

As assumed in D1.1, the flexibility offered by DER assets and the one requested by DSOs will be correlated with their location in the distribution grid since congestion issues have local and not systemic characteristics. Moreover, close to real time measurements will be provided for analysis of the network voltage profile. Considering this, the storage assets will be equipped with PEDs enabling such functionalities.

3.1.3 HLUC 03: Real time detection of uncontrolled islanding by leveraging storage flexibility

3.1.3.1 Overview

The detection and mitigation of uncontrolled islanding requires advanced monitoring and observability of the grid not only at substation or feeder level but real time monitoring at PED/DER asset level. In this respect, DSOs are capable of monitoring and assessing in real time the operational behavior of the network's and, if available, the DERs' protection system. In case of inconsistences under faulted grid conditions, a mitigation plan should be scheduled and implemented by sending set-points to the PED assets and trigger grid reconfiguration in order to avoid human safety risks. The Island Power Management Application (IPMA) of the DSO Toolbox, which will be developed within the framework of this project, is responsible for detecting and mitigating uncontrolled islanding situations.

3.1.3.2 Scenarios

3.1.3.2.1 Cyprus

HLUC03 will not be demonstrated in the Cypriot pilot.

3.1.3.2.2 Germany

HLUC03 will not be demonstrated in the German pilot.

3.1.3.2.3 Spain

This use case will be tested in the Spanish pilot, more specifically in the location of L'Esquirol, exploiting the PED and batteries already installed on site.

As assumed in D1.1, close to real time measurements will be provided for the analysis of the network operation. In light of this, PEDs are already installed and operable and monitorable at strategically selected assets. An agreement between the DSO and the PED/DER owners (UPC) is made for the realization of this use case. Such bilateral agreements concern the provision of monitoring and control capabilities from the PED/DER directly to the DSO.

3.1.4 HLUC 04: Self-healing operation after critical event considering DER & grid flexibility

3.1.4.1 Overview

This use case intends to give response for temporary events, including those provoked by extreme weather conditions as strong wind episodes or storms, causing temporary and localized affectation to the grid (outage). Self-healing process after fault occurs in the network entails the identification of the grid boundaries affected by the fault and the extraction of a mitigation plan, in terms of both grid and DER flexibility, to minimize the isolated area and maximize the electrified grid end-users.

3.1.4.2 Scenarios

3.1.4.2.1 Cyprus

HLUC04 will not be demonstrated in the Cypriot pilot.

3.1.4.2.2 Germany

HLUC04 will be worked out in two subnets, one in Schönbrunn and one in Breitenbrunn. The substations are equipped with Power Quality (PQ) metering systems and the interval of measuring will be set to 10 seconds. These smart meters implemented, and further preparations regarding the High-Level Power Management will help to prepare the grid to a suitable test facility where the future tests can be performed.

3.1.4.2.3 Spain

This use case will be tested in in the location of L'Esquirol, exploiting the PED and batteries already installed on site, and the switchgears for grid reconfiguration.

Grid reconfiguration entails the proper scheduling of the switchgear's operational status to modify the network power flows such that the number of non-electrified grid end users is the minimum possible. The Switchgear Dispatch Scheduler (SDS) is the responsible application for ordering and assessing the switchgear status modification through the SCADA system (DS- SCADA) and at the time established in the schedule.

In case that grid reconfiguration provokes additional network operational issues, i.e. network congestion or voltage excursions, the flexibility offered by the dispatchable DER units is exploited.

As assumed in D1.1, bilateral agreements are adequately defined so as to contain all the details (i.e. flexibility capacity, spatial indication of DERs relevant to electricity grid, etc.) for activating the flexibility in every situation requested by the DSO.

3.1.5 HLUC 05: Flexibility exploitation for islanded microgrid operation

3.1.5.1 Overview

Microgrid can operate either in interconnected or in islanded mode. DSO can benefit from microgrid islanding operation, as critical loads within the islanded area will remain connected, aiming to the maximum possible power supply reliability. In islanding operation, the Microgrid Operator (MgO) can leverage the flexibility capabilities within microgrid context to ensure security of supply within microgrid and ensure the reliability of the distribution grid. The storage converters support the islanding operation by providing voltage and frequency references as well as serve the critical loads by offering flexibility when possible. The Microgrid Flexibility Management System (MgFMS) schedules the available DER flexibility so as to keep the energy cost as low as possible.

3.1.5.2 Scenarios

3.1.5.2.1 Cyprus

This use case will be demonstrated in the grounds of PVTL of UCY (UCY nanogrid). The Campus nanogrid consists of distributed generation (PV generators), distributed storage and loads. The objective is to ensure continuous supply to critical loads by using the nanogrid's generating units with support from the flexibility of storage and controllable loads in an economic manner. Converter-based assets and flexible DERs will be used to retain voltage and frequency limits.

Islanding operation mode of the nanogrid will be realized via real-time Hardware-in-the-Loop (HIL) approach.

3.1.5.2.2 Germany

HLUC05 will not be demonstrated in the German pilot.

3.1.5.2.3 Spain

HLUC05 will not be demonstrated in the Spanish pilot

3.1.6 HLUC 06: Leveraging DER flexibility towards enhancing network operational efficiency

3.1.6.1 Overview

Under a high RES penetration scenario in distribution network, there is a need for increasing the local consumption of RES production at primary or secondary substation level. The exploitation of dispatchable distributed production/consumption/storage assets for better matching the consumption and generation profiles locally as well as for shedding network peak demands will enable better exploitation of the existing grid capacity.

3.1.6.2 Scenarios

3.1.6.2.1 Cyprus

HLUC06 will not be demonstrated in the Cypriot pilot

3.1.6.2.2 Germany

According to par. 15 of the German regulation on electricity feed-in to and consumption from electricity supply grids local utility companies have to prepare a prediction plan. [5]

The testability for the German pilot will be shown as the time taken to activate “x” amount of flexibility through local demand reduction measures.

We expect no constraints.

3.1.6.2.3 Spain

This use case will be tested in the locations of L’Esquirol, Vallfogona and Estabanell headquarters with the V2G. Moreover, the industrial clients participating in the project will actively take part of the scenario.

As defined before in Chapter 2, at least three factories will be involved. Depending on the pre-defined time horizon, an energy forecast of the production and consumption profiles in the grid area under study will be carried out in order to identify the unbalances between generation and demand.

As assumed in D1.1, bilateral agreements have been defined so as to contain all the details (i.e. flexibility capacity, spatial indication of DERs relevant to electricity grid, etc.) for activating the flexibility in every situation requested by the DSO.

The flexibility offered by DER assets and the one requested by DSOs are correlated with their location in the distribution grid since congestion issues have local and not systemic characteristics.

3.1.7 HLUC 07: Improving power quality and reducing losses through power electronics

3.1.7.1 Overview

This UC provides a high-level description of the process for improving power quality (in terms of waveform quality) by making use of the PEDs which provide the requested monitoring and control capabilities. The Power Quality Service (PQS) according to the grid monitoring and observability proposes an optimal scheduling for power quality operation of the PEDs. The schedule is executed by PEDs. The remuneration of power services offered by PED owners is realized through bilateral agreements with the DSOs, after strategic allocation analysis, facilitating remote monitoring and control access of PEDs.

3.1.7.2 Scenarios

3.1.7.2.1 Cyprus

HLUC07 will not be demonstrated in the Cypriot pilot.

3.1.7.2.2 Germany

HLUC07 will not be demonstrated in the German pilot

3.1.7.2.3 Spain

This use case will be tested in the Spanish pilot. Still to be defined, it will be in one or the two locations of L'Esquirol and Vallfogona.

As assumed in D1.1, close to real time measurements will be provided for the analysis of the network operation. Considering this, PEDs have been installed and are operable at strategically selected assets. Bilateral agreements between the DSO and the PED owners have been defined for the realization of this use case. Such bilateral agreements concern the provision of monitoring and control capabilities from the PEDs/DERs directly to the DSO. The grid configuration, locations and operational status of iDERs, PEDs and circuit breakers will be known by the PQS, In order for this to devise a mitigation strategy for the improvement of power quality.

3.1.8 HLUC 08: Economically optimized flexibility leveraging for a grid-connected microgrid

3.1.8.1 Overview

This use case aims to highlight the role of a microgrid as a Flexibility Service Provider offering flexibility services to support network operation. The primary consideration of the Microgrid Operator (MgO) when scheduling microgrid's flexibility capacities is to minimize expenditure and maximize flexibility trading associated revenue, while ensuring that all systems are functional and there are no noticeable inconveniences. At the same time, prosumers within the microgrid context trade their flexibility having in mind to minimize their energy bills and/or maximize their profits from trading. This use case focuses on the MgO's objective to achieve the most economically effective flexibility solution serving DSOs flexibility request, aiming to maximize the trading profits and at the same time maintain the operation costs in the lowest possible levels.

3.1.8.2 Scenarios

3.1.8.2.1 Cyprus

This use case will be demonstrated in the Cypriot pilot by utilizing flexibility of DERs of the UCY campus, microgrid and nanogrid. The objective is to maximize the profit of the Aggregator/MgO while respecting users' preferences and constraints. The focus of this scenario is on flexibility of active power which can be obtained from load, generation, and storage units. In the Cypriot pilot, flexibility mainly stems from the ability to control/affect the operation of the electrical chillers which are used for the cooling system of the UCY campus (thermal energy vector). Additional flexibility is obtained from the assets of the PVTL nanogrid, which includes PV generation and storage, and will be expanded to further include a controllable electronic load, smart plugs and controllable devices. As there is no DSO participation in the Cypriot pilot, flexibility requests will be based on operating scenarios and the main objective of this demonstration is the ability to effectively manage the flexibility of DERs and orchestrate their operation.

3.1.8.2.2 Germany

HLUC08 will not be demonstrated in the German pilot.

3.1.8.2.3 Spain

HLUC08 will not be demonstrated in the Spanish pilot.

3.1.9 HLUC 12: Creating dynamic tariffs based on flexibility use in the actual regulatory framework

3.1.9.1 Overview

This use case implements an advanced dynamic pricing mechanism for the procurement of flexibility in the congestion and overload states of the grid and remuneration for costs of extraction of flexibilities in the scope of equivalent or actual sequential operational close down of DER at distribution level. Capacity-driven network tariffs and time-of-use consumer tariffs which internalize these network tariffs are not tailored for this task, neither in the spatial nor in the temporal dimension. What is sought after is a means of pricing at the distribution level which can potently generate prices with high spatial and temporal resolution. Two governing principles will be employed: i) the pricing has to be dependent on and balanced with the income of the DSO based on avoided cost by TSO to remedy these situations., ii) remuneration to the prosumer has to cover the costs of extraction of flexibilities in the scope of equivalent or actual sequential operational close down of operation of process.

3.1.9.2 Scenarios

3.1.9.2.1 Cyprus

HLUC12 will not be demonstrated in the Cypriot pilot.

3.1.9.2.2 Germany

Flexibility tariffs can be created by implementing, for instance, pay-as-you go possibilities. The flexibility tariffs in the German pilot are set by the retailers for trading. If there was physical flexibility this would be the duty of the DSO. The tariffs will be applicable for all pilot site customers.

An example for these tariffs are partner tariffs for aggregators and prosumers to share the profits from flexibility aggregation equally. This is meant to be a compensation for the interference into the sovereignty of the prosumer's production management. Therefore, the more interference the prosumer allows the more money he or she gets.

As for dynamic tariffs, different tariffs can be determined depending on whether the providing partner chooses a demand contract or an acquiescence, which is then can be accompanied by a, e.g., exponential remuneration the more this partner allows. In addition, out of scope of pre-agreed measured as well as times of day and years, as well as generation types will be also remunerated accordingly using different tariffs.

Some incentives may include Monetary trading agreements involving physical (cash) or digital (electronic transfer or decentralized - FlexCoin). Another monetary way as incentives can come in a form of CO2-pricing. Each citizen is allocated with a "CO2-budget". Exceeding or falling short will be answered with penalty or remuneration respectively. Non- monetary trading involves change of goods in a barter or a Local Exchange Trading System (LETS) form or another "payment" method (e.g. pseudo-currency).In this case a producer/prosumer offers energy to the members of the peers and they, in exchange, provide the seller with services within their ability, for instance: painting houses, food, etc. Another way of reciprocating would be a "communal pot", to which a predetermined amount of money per predetermined time period ought to be paid. This money then, can be used for maintenance purposes, etc.

3.1.9.2.3 Spain

HLUC12 will not be demonstrated in the Spanish pilot

3.1.10 HLUC 13: Improving the outcome in flexibility by introducing sector coupling

3.1.10.1 Overview

To fully integrate distributed RES into a local LV/MV grid the overall energy production and consumption are to be considered. With the main focus on electricity, the coupling with other sectors of a utility company shall be established for flexibility trading. With the use of CHP systems and other sector coupling technologies (e.g. Power-to-Gas plant) energy/flexibility can be shifted into the sectors gas and heat. The hydrogen converted energy can be converted back into electricity or heat via CHP plants. The overall flexibility extraction process is enhanced with the coupling of the former mentioned sectors aiming to improve the outcomes of the flexibility trading.

3.1.10.2 Scenarios

3.1.10.2.1 Cyprus

HLUC13 will not be demonstrated in the Cypriot pilot.

3.1.10.2.2 Germany

In order to optimise operation, the two district heating generation systems, using an CHP, in Wunsiedel, i.e. Schönbrunn and Breitenbrunn, were installed with Power Quality (PQ) measurement boxes. These two locations offer a look into how sector coupling can be used as a flexibility aggregator by SWW.

3.1.10.2.3 Spain

HLUC13 will not be demonstrated in the Spanish pilot.

3.1.11 HLUC 14: Form a first example of a regional flexibility exchange model

3.1.11.1 Overview

This use case introduces a regional marketplace and marketplace operator for trading energy flexibilities as opposed to trading of energy products. The competitors are BRPs both on supply and demand sides.

This energy flexibility exchange could run in parallel to existing energy exchange and would focus on transients close to real time, reducing the need for tertiary and secondary reserves in the system.

The trading system is operated by an independent Market Operator.

3.1.11.2 Scenarios

3.1.11.2.1 Cyprus

HLUC14 will not be demonstrated in the Cypriot pilot.

3.1.11.2.2 Germany

As mentioned in section 2.3.2 – for the purpose of this HLUC a so-called Flexibridge built on LECs is in the making.

This bridge will be conducted by an internal BRP and can and will be used to bridge between SWH and SWW, as there is no other market available. The balance sheet adjustment is used and normal utility business of an upstream DSO is run. (cf. 2.3.2)

There is no link to other HLUCs.

3.1.11.2.3 Spain

HLUC14 will not be demonstrated in the Spanish pilot.

3.1.12 HLUC 15: P2P flexibility trading

3.1.12.1 Overview

This use case will demonstrate automated trading of flexible energies (electricity, heat) in the context of energy communities. While energy communities can exist on multiple levels, this use case concentrates on prosumer-centric communities. There shall be no limitation to the size and form of peers in the community. While the community shall mostly comprise small prosumers (like residential homes) and small business entities (e.g. companies with generators or storage), VPPs, SMEs and local utilities are not excluded if they act as peers with the same rights and obligations. A specific role in the energy community can link it to other such communities and other energy markets. Governance policies and incentive mechanisms like special tariffs or pseudo-currencies will be explored. For the realization of this use case, the Flexibility Trading Platform will be coupled with the P2P market toolbox using Distributed Ledger Technologies.

3.1.12.2 Scenarios

3.1.12.2.1 Cyprus

HLUC15 will not be demonstrated in the Cypriot pilot.

3.1.12.2.2 Germany

The concept of P2P trading touches two “main” exchange properties of goods and services:

1. Conventional trading agreements involving physical (cash) or digital (electronic transfer or decentralized e.g. Bitcoin)
2. “Unconventional” trading involves change of goods in a barter or a Local Exchange Trading System (LETS) form or another “payment” method (e.g. pseudo-currency).
3. Both ways could be implemented into flexibility aggregation and trading by modifying the exchange for the vary “currency”

Local exchange trading systems organizes a trading platform for services and goods between members of and within a pre-decided group. This groups might create a local group-currency and/or will use a barter trading scheme. In this case a producer/prosumer offers energy to the members of the peers and they, in exchange, provide the seller with services within their ability, for instance: painting houses, sharing food, etc.

Another way of reciprocating would be a “communal pot”, to which a predetermined amount of money per predetermined time period ought to be paid. This money then, can be used for maintenance purposes, etc.

3.1.12.2.3 Spain

HLUC15 will not be demonstrated in the Spanish pilot.

3.2 Summary

Table 9: HLUC testability per pilot

#	HLUC Name	Spain	Germany	Cyprus
1	Advanced network congestion management considering DER & grid flexibility (seasonal, day-ahead, etc)	x	x	
2	Voltage compensation via reactive power procurement	x	x	x
3	Real time detection of uncontrolled islanding by leveraging storage flexibility	x		
4	Self-healing operation after critical event considering DER & grid flexibility	x	x	
5	Flexibility exploitation for islanded microgrid operation			x
6	Leveraging DER flexibility towards enhancing network operational efficiency	x	x	
7	Improving power quality and reducing losses through local storage utilization	x		
8	Economically optimised flexibility leveraging for a connected microgrid			x
12	Creating dynamic tariffs based on flexibility use in the actual regulatory framework		x	
13	Improving the outcome in flexibility by introducing sector coupling		x	
14	Form a first example of a regional flexibility exchange model		x	
15	P2P flexibility trading		x	

4 Validation Methodology

4.1 Overview

This section shall give a basic outline regarding the definitions of the KPIs as well as their validation methods and in which demo-site they will be carried out.

In this chapter a series of metrics will be defined, with which the demos can assess, whether the goals set for each of the pilot in the beginning of the project can be validated (technical, functional, impact-oriented). The assessment of these metrics (to be done in T7.3) will provide interesting insights for a diverse set of stakeholders (solution providers, prosumers, aggregators, utilities, grid operators).

Table 10 and Table 11 summarize the quantifiable indicators that were listed as relevant to FEVER either at the proposal preparation or at the project implementation phase. These KPIs are grouped to project-level KPIs (i.e. calculation of the impact of the implemented solutions at the broader sense) and technical-level KPIs (i.e. calculation of the performance of specific technical components).

4.2 Project-level KPIs

Table 10: Project-level KPIs

ID	Name	Description	Relevant HLUC
DOA_01	Distributed storage integration	Distributed storage integration in the grid (per pilot): Capacity, Energy	All
DOA_02	Reduction of peak active power from V2G/EV	V2G and EV management: Reduction of peak active power consumption of the grid	HLUC13
DOA_03	Power-2-X flexibility aggregated	Power-2-cold flexibility steps power Maximum aggregated power2cold flexibility	HLUC01, HLUC13
DOA_04	Distribution grid stability through responsiveness of flexibility services	Time required to activate portion of load flexibility through DR services	HLUC01
DOA_05	Flexibility of virtual energy storage	Flexibility generated by virtual energy storage in demonstrated use cases (energy demand variation (delta MWh /h) with respect to peak demand (MWh/h))	All
DOA_06	Critical event prediction	Critical event prediction (missed incidents)	HLUC01
DOA_07	Losses reduction	Losses reduction due to local use of energy (shift towards the “zero km” paradigm) and the optimal operation of storage converters (harmonic compensation, reactive power compensation, balancing).	HLUC06, HLUC07
DOA_08	Short term spatio-temporal forecasting errors	Short term spatio-temporal forecasting errors (RMSE)	HLUC01, HLUC02, HLUC04, HLUC05, HLUC06, HLUC08

DOA_09	Peak demand reduction	Peak demand reduction (ratio of average and maximal daily power)	HLUC01, HLUC06
DOA_10	Fault detection and localization	Fault detection and localization (missed incidents)	HLUC4
DOA_11	Peak demand reduction (MV/LV transformer)	Peak demand reduction, as measured at the MV/LV transformer	HLUC01, HLUC06
DOA_12	Increasing the RES hosting capacity at the distribution grid	Increasing the RES hosting capacity at the distribution grid for protection of citizens from electrical outrages and other problems	All
DOA_13	Maximization of the use of infrastructures	Maximization of the use of actual infrastructures through active energy management and balancing at LV level as reflected in CAPEX and OPEX	All
DOA_14	Increase power quality	Power quality: local supply voltage profiles: amount of time outside 5% of nominal	HLUC02, HLUC07
DOA_18	CO2 emissions reduction	Percentage reduction in CO2 emissions (with respect to the values at the beginning of the project)	All
DOA_19	Secure information and communication technologies	Expresses the number of vulnerabilities detected in relevant scenarios to the solution	All
DOA_20	Integration performance	KPIs associated with the integration middleware - Number of transactions flowing through the bus (Throughput) - Percentage of processes where completion falls within +/- 5% of the estimated time completion - Connectivity: - Reuse -Latency: Speed and processing throughput of transactions	All

4.3 Technical solution level KPIs

Table 11: KPI Description

ID	Name	Description	Relevant HLUC
KPI_PUC01_1	Responsiveness of close-to real time prevention	Expresses the time required for identifying the potential violation and proposing the mitigation actions in the close-to real time scenario.	HLUC01

KPI_PUC01_2	Performance of critical event forecasting	True positive, false positive (false alarms), true negative and false negative (missed detections) ratios of forecasted critical events.	HLUC01
KPI_PUC02_1	Responsiveness of grid Reconfiguration planning	Expresses the time required for identifying the series of commands of grid switchgear	HLUC01, HLUC04
KPI_PUC02_2	Efficiency of grid Reconfiguration planning	Expresses the amount of valid dispatches of the plan, with respect to the total requested.	HLUC01, HLUC04
KPI_PUC06_1	Congestion management effectiveness	Average efficiency of congestion management actions.	HLUC01, HLUC02, HLUC04, HLUC06
KPI_PUC06_2	Voltage compensation effectiveness	Average efficiency of voltage compensation actions.	HLUC01, HLUC02, HLUC04, HLUC06
KPI_PUC06_3	Loss compensation effectiveness	Average efficiency of technical loss reduction actions.	HLUC01, HLUC02, HLUC04, HLUC06
KPI_PUC06_4	Self healing effectiveness	Average efficiency of self-healing reduction actions.	HLUC01, HLUC02, HLUC04, HLUC06
KPI_PUC07_1	Responsiveness of close-to real time prevention	Expresses the time required for identifying the potential violation and proposing the mitigation actions.	HLUC02
KPI_PUC08_1	Island´s detected	Expresses the percentage of successful island detections.	HLUC03
KPI_PUC09_01	Responsiveness of close-to real time mitigation	Expresses the time required for de-energizing the uncontrolled island after the mitigation request.	HLUC03
KPI_PUC09_02	Islands mitigated	Expresses the percentage of successfully mitigated uncontrolled islanding situation problems.	HLUC03
KPI_PUC10_1	Power Quality Indicator	Expresses the percentage of successful detection of power quality requirement violations.	HLUC07
KPI_PUC11_01	Improvement of power quality	Expresses the reduction of losses due to reduction of harmonics and reduction of imbalances in	HLUC07

		presence of lack of power quality.	
KPI_PUC12_1	Responsiveness of self healing	Expresses the time required for identifying the fault and proposing the mitigation actions.	HLUC04
KPI_PUC13_1	Loss reduction	Percentage of loss reduction wrt BAU.	HLUC06
KPI_SUC01_1	Performance of forecasting	Accuracy of the forecasting: Mean absolute percentage error (MAPE)	HLUC01, HLUC02, HLUC04, HLUC05, HLUC06, HLUC08
KPI_SUC02_1	Data received	Percentage of data received vs expected per time period.	HLUC01, HLUC02, HLUC03, HLUC04, HLUC06, HLUC07
KPI_SUC02_2	Frequency of data received	Percentage of data received in expected refreshing period.	HLUC01, HLUC02, HLUC03, HLUC04, HLUC06, HLUC07
KPI_SUC02_3	Consistency of data received	Percentage of consistent data.	HLUC01, HLUC02, HLUC03, HLUC04, HLUC06, HLUC07
KPI_SUC04_1	Performance of planning	Measured in terms of improvement of the optimisation criteria.	HLUC01, HLUC02, HLUC04, HLUC06
KPI_SUC05_1	Asset state response time	Asset monitoring response time is defined and respected (within agreed limits).	HLUC04, HLUC05, HLUC06
KPI_SUC05_2	Asset control reaction time	Asset control reaction time is defined and kept (within agreed limits).	HLUC04, HLUC05, HLUC06
KPI_SUC10_1	Performance of fault detection	Ratio of false alarms and missed detections	HLUC04
KPI_PUC03_1	Amount of requested energy flexibility	Expresses the total amount of energy deviation (ΔkWh) **requested** by a flexibility service consumer (e.g., DSO, BRP).	HLUC01, HLUC05, HLUC08
KPI_PUC03_2	Amount of delivered energy flexibility	Expresses the total amount of energy deviation (ΔkWh) **delivered** in a response to a flexibility request.	HLUC01, HLUC05, HLUC08
KPI_PUC03_3	Total flexibility request cost	Expresses the total flexibility service consumer (e.g., DSO, BRP) cost incurred for requesting flexibility services.	HLUC01, HLUC05, HLUC08
KPI_PUC04_1	Amount of offered energy flexibility	Expresses the total amount of energy flexibility (ΔkWh) **offered** by the	HLUC04, HLUC05, HLUC06, HLUC08, HLUC09, HLUC12, HLUC13, HLUC14

		flexibility service provider.	
KPI_PUC04_2	Amount of delivered energy flexibility	Expresses the total amount of energy flexibility (ΔkWh) **delivered** in response to a market order	HLUC04, HLUC05, HLUC06, HLUC08, HLUC09, HLUC12, HLUC13, HLUC14
KPI_PUC04_3	Total reward	Expresses total reward obtained for issuing flexibility services.	HLUC04, HLUC05, HLUC06, HLUC08, HLUC09, HLUC12, HLUC13, HLUC14
KPI_PUC05_1	Prosumer reliability	Describes how well certain flexibility providers deliver the traded flexibility.	HLUC01, HLUC04, HLUC05, HLUC06, HLUC08, HLUC09, HLUC12, HLUC13, HLUC14, HLUC15
KPI_PUC22_01	Target SoC reached	Expresses the percentage of target SoCs reached.	HLUC06, HLUC13
KPI_PUC22_02	Economic benefit of using FEVER EV charging	Expresses the economic benefit of using FEVER EV charging.	HLUC06, HLUC13
KPI_PUC27_1	Daily Number of interventions	The number of interventions within 24 h to compensate for deviations from planning.	HLUC13
KPI_PUC27_2	Amount of needed energy flexibility	The amount of energy flexibility needed by the BRP management system over a given period of time e.g. day or month (tbd).	HLUC13
KPI_PUC27_3	External procurement	Internal prioritization of own generation, storage and flexibility depending on price signals; External procurement below the specified value.	HLUC13
KPI_PUC29_1	Critical loads connectivity	Critical loads which need to remain connected in islanding operation.	HLUC05
KPI_PUC29_2	Frequency regulation	Frequency to be retained within limits in islanding operation.	HLUC05
KPI_PUC29_3	Voltage regulation	Voltage to be retained within limits in islanding operation.	HLUC05
KPI_PUC29_4	Power supply continuity	Expresses the continuous supply of power to customers' loads in islanding operation.	HLUC05
KPI_PUC29_5	Flexible loads	Expresses the relative number (percentage)	HLUC05

		of flexible loads available in the pilot area.	
KPI_PUC29_6	Trading flexibility	Evaluation of DER utilization for ancillary services.	HLUC05, HLUC08
KPI_PUC29_7	Operation cost	Change of operation cost due to the management and trade of flexibility.	HLUC08
KPI_PUC31_1	External procurement	Internal prioritization of own generation, storage and flexibility depending on price signals; External procurement below the specified value	HLUC14
KPI _PUC32_1	Transaction processing throughput	Expresses the throughput of transaction processed by the platform platform should be scalable and able to process high throughput of number of flexibilities traded between peers.	HLUC15
KPI _PUC32_2	Number of peers	Number of peers that are actively participating in the peer to peer trading platform by requesting and offering flexibilities.	HLUC15
KPI_SUC06_1	Number of Flex-Offers per time unit	Expresses a total number of Flex-Offers generated within a time unit	HLUC04, HLUC05, HLUC06, HLUC08, HLUC09, HLUC12, HLUC13, HLUC14
KPI_HLUC03	Reduction of interruption duration/ frequency	Reduction of system average interruption duration / frequency index	HLUC03

4.4 Calculation Methodology

4.4.1 DOA_01: Distributed storage integration

4.4.1.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Distributed storage integration in the grid (per pilot): Capacity Energy	**Overreaching**	**SWW&SWH(EST & UCY)**	**ALL**

4.4.1.2 Calculation

The total distributed storage capacity energy is given by the summation of all asset's capacities connected to the grid:

$$DOA\_01 = \sum_{i=1}^{n} a_i$$

Where:

a represents the total asset capacity in Ah

i represents the type of equipment (EV, BESS, power2cold, demand response etc.)

n represents the total number of assets integrated

The number of assets integrated and type will vary depending on the pilot.

4.4.1.3 Observations

In order to sum up coherently the storage integration of different types of asset, their electric capacity must be first described in kWh. For EV's and BESS usually their capacity is expressed either in kWh or directly in Ah. For virtual storage such as Demand Response (DR) and Power2cold (P2C), the electric capacity is calculated by the amount of energy reduction provided by the usage of such assets. **Error! Reference source not found.**3 represents an example of the effects of using DR by reducing a daily load profile, which has a similar effect as the usage of P2C.

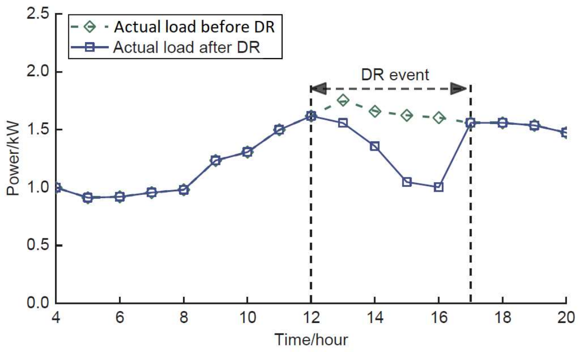

Figure 13: Effects of demand response in power systems. Adapted from Invalid source specified.

In both cases the electric capacity (in kWh) is calculated by the following equation:

$$E = \int_{t1}^{t2} P_{net} \, .dt \ [kWh]$$

Where,

P_{net}: Power difference resulted by the usage of virtual storage

t_1: Starting time of using virtual storage

t_2: Ending time of using virtual storage

The asset capacity a is then computed by dividing the electric capacity E by the rated voltage of the asset V:

$$a = \frac{E}{V} \times 1000 \ [Ah]$$

4.4.2 DOA_02: Reduction of peak active power from V2G/EV

4.4.2.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
V2G and EV management: Reduction of peak active power consumption of the grid	**HLUC13**	**UPC**	**DE**

4.4.2.2 Calculation

The computation of the peak active power reduction will follow the equation:

$$DOA\_02 = 1 - \frac{P'}{P} \times 100\ [\%]$$

Where,

P’ is the peak active power consumption in the presence of V2G/EV’s in [kW]

P is the ordinary peak active power consumption without V2G/EV’s [kW]

4.4.2.3 Observations

The peak values for active power are obtained through an analysis of several days, half of each the EV/V2Gs will be connected. Then, the peak active power consumption will be the average of all days analysed for each scenario (with and without EV/V2G).

4.4.3 DOA_03: Power-2-X flexibility aggregated

4.4.3.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Power-2-cold flexibility steps power Maximum aggregated power2cold flexibility	**HLUC01, HLUC13**	**SWH&EST**	**DE,CY**

4.4.3.2 Calculation

The amount of time the cooling system allowed to be turned off without causing damage to the general system/plant shall be determined. In addition, the time it takes for the cooling system to regain “full power” shall be measured.

Then, the amount of power per “x”-time will be determined.

$$t_y = t - t_x$$

t_y is the duration the system allowed to be turned off. **t_x** is the duration the system needs to regenerate. **t** is the total amount of time.

$$DOA\_03a = P_i = \frac{E}{t_{yi}}$$

P_i is the amount of power [in kW] can be used for flexibility.

$$DOA\_03b = \sum_{i=1}^{n} P_i$$

4.4.3.3 Observations

Remunerations for flexibility are carried out as for the duration the power was needed.

The formula should work in both directions of the Flexibility. Depending on the general conditions in the operation of the systems, the electrical power can be below or above the optimal operating point or the target temperature can be reached faster or slower, or possibly also briefly above/below. Thus, the time element in connection with the supplied energy would be a flexibility to be calculated. The power the system can undertake without harming the equipment and rooms etc. should be taken into consideration.

4.4.4 DOA_04: Distribution grid stability through responsiveness of flexibility services

4.4.4.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Time required to activate portion of load flexibility through DR services	**HLUC01**	**SWW (& all partners)**	**DE,CY**

4.4.4.2 Calculation

Time required to activate portion of load flexibility through DR services.

This shall be done using the locally implemented EMS.

$$DOA\_04 = T_{(DR)} = T_{(i)} - T_{(x)}$$

Where

$T_{(DR)}$ is the time required by the DR service

$T_{(i)}$ is the time instance given by (Delivered Flexibility) * t

$T_{(x)}$ is the time that X% from requested time was delivered

4.4.5 DOA_05: Flexibility of virtual energy storage

4.4.5.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Flexibility generated by virtual energy storage in demonstrated use cases (energy demand variation (delta MWh /h) with respect to peak demand (MWh/h))	**Overreaching**	**INEA(/EG)**	**All**

4.4.5.2 Calculation

The KPI measures the adaptation capacity as energy demand variation with respect to peak demand (MWh/h). The performance indicator for flexibility is defined as:

$$DOA\_05 = K_{2.5} = \frac{ABS(E_{flex})}{MAX\left(ABS(E_{meas}),\ ABS(E_{flex} + E_{meas})\right)}$$

where:

E_{meas} is total prosumer's measured energy and is $E_{meas} > 0$ for production and $E_{meas} < 0$ for consumption.

E_{flex} is total prosumer's offered flexible energy and is $E_{flex} > 0$ for production enlargement (equivalent to consumption reduction) and $E_{flex} < 0$ for production reduction (equivalent to consumption enlargement).

4.4.5.3 Observations

The performance indicator is calculated separately for production enlargement (K_{flex+}) and production reduction (K_{flex-}).

4.4.6 DOA_06: Critical event prediction (missed incidents)

4.4.6.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Critical event prediction (missed incidents)	**HLUC01**	**UdG**	**DE,ESP**

4.4.6.2 Calculation:

See KPI_PUC01_2: False Negative Rate (FNR)

Observations

4.4.7 DOA_07: Losses reduction

4.4.7.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Losses reduction due to local use of energy (shift towards the "zero km" paradigm) and the optimal operation of storage converters (harmonic compensation, reactive power compensation, balancing).	**HLUC06, HLUC07**	**UdG**	**DE,ESP**

4.4.7.2 Calculation

See KPI_PUC11_01 (resp. UPC)

4.4.8 DOA_08: Short term spatio-temporal forecasting errors

4.4.8.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Short term spatio-temporal forecasting errors (RMSE)	**HLUC01, HLUC02, HLUC04, HLUC05, HLUC06, HLUC08**	**UdG & UCY**	**DE,CY,ESP**

4.4.8.2 Calculation

See KPI_SUC01_1: B)

4.4.9 DOA_09: Peak demand reduction

4.4.9.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Peak demand reduction (ratio of average and maximal daily power)	HLUC01 HLUC06	INEA	DE,CY,ESP

4.4.9.2 Calculation

The KPI monitors a coefficient calculated as ratio of maximal and average daily power

$$DOA\_09 = K_{peak} = \frac{P_{max}}{P_{avg}}$$

Where,

P_{avg} as average daily power calculated as daily energy consumption divided by 24 hrs

P_{max} is daily max 15 min or 60min average value.

The KPI is calculated as a ratio of the coefficient historical values

$$DOA\_09 = \frac{K_{peak\_pilotPeriod}}{K_{peak\_baselinePeriod}}$$

Where,

$K_{peak\_pilotPeriodvg}$ is average of coeficient's daily values over the FEVER evaluation period and

$K_{peak\_baselinePeriod}$ is average of coeficient's daily values before evaluation period.

4.4.9.3 Observations

The peak demand reduction is estimated by the comparison of the historic KPI values. The reduction of the peak demand results in the KPI value decrease.

4.4.10 DOA_10: Fault detection and localization (missed incidents)

4.4.10.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Fault detection and localization (missed incidents)	HLUC04	UdG	DE,ESP

4.4.10.2 Calculation

See KPI_PUC01_2: False Negative Rate

4.4.11 DOA_11: Peak demand reduction (MV/LV transformer)

4.4.11.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots

Peak demand reduction, as measured at the MV/LV transformer	**HLUC01 HLUC06**	**INEA**	**DE,CY,ESP**

4.4.11.2 Calculation

The KPI is calculated in the same way as DOA_09 (4.4.9)

4.4.11.3 Observations

The KPI is calculated on the aggregated level of the whole grid area/demo site.

4.4.12 DOA_12: Increasing the RES hosting capacity at the distribution grid

4.4.12.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Increasing the RES hosting capacity at the distribution grid for protection of citizens from electrical outrages and other problems	**Overearching**	**EST**	**ESP**

To protect citizens from electrical outages and problems derived from an excessive and uncontrolled installation of DERs, each country defines and regulates the maximum hosting capacity based on rules-of-thumb criteria. In Spain, the total DG rated power should be lower than the 50% of the transformer rated power, lower than 50% of the thermal limit of the affected feeders and lower than 10% of the short circuit capacity of the point of common coupling (PCC).

These rates of installed capacity are not common in Spanish territory, and in general it is unlikely, nowadays, to have technical issues related to DERs generation. The same applies to the FEVER pilot area. The main risks associated to the DERs installation are over-voltages, feeder over-loading, reduction of waveform quality and increase of protection faults.

4.4.12.2 Calculation

For this DOA calculation both the maximum generated power in the BAU situation and with FEVER technology need to be known, in order to calculate the RES hosting capacity of the power grid.

First of all, the maximum capacity of the grid in the BAU situation will be calculated considering the physical limits imposed by the network type. The power will be calculated according to the following formula:

$$P_{max} = V_{max} \cdot I_{max}$$

Where:

V_{max} is the maximum voltage of the three-phase network;

I_{max} is the maximum distribution capacity [A] of the network.

The increment of the hosting capacity of the power grid will be calculated as follows:

$$\Delta Hc = x \cdot P_{max} + P_{FEVER} = x \cdot P_{\max} + \sum Pc + \sum PED$$

Where:

The maximum power P_{max} is multiplied by a percentage factor *x* that is defined by the Spanish Government to limit the power generated in a renewable distribution network (managed by the distributors in the same network in the same network with respect to the consumption capacity).

P_{FEVER} is the flexible capacity generated with FEVER technology, which is calculated as the sum of all the capacities P_C given by all the clients involved in FEVER Spanish Pilots and the sum of the PEDs installed within FEVER Spanish Pilots.

Finally, the DOA12, that represents the percentage increase in the RES hosting capacity, will be calculated according to the below formula:

$$DOA\_12 = \frac{\Delta Hc - \% \cdot P_{max}}{\% \cdot P_{max}} 100\%$$

4.4.13 DOA_13: Maximization of the use of infrastructures

4.4.13.1 Overview

Title	Relevant HLUCs	Responsible Party	Relevant Pilots
Maximization of the use of infrastructures	**Overeaching**	**EST**	**ESP**

4.4.13.2 Calculation

Maximization of the use of actual infrastructures through active energy management and balancing at LV level as reflected in CAPEX and OPEX (% of CAPEX and OPEX yearly budget for electricity grid)

This part of the KPI aims at monitoring the capital costs (CAPEX) associated to the FEVER technology and make sure they do not overcome the capital costs of a BAU solution.

First, a traditional infrastructure investment will be considered, consisting of a LV line together with a transformer. An average distance needs to be assumed, and a cost of the line per meter is known:

$$C_{LVnetwork}\,[€] = length\,[m] \cdot cost\,[€/\mathrm{m}]$$

Considering this cost together with an average cost of a transformer, the total cost of the traditional infrastructure is the addition of these costs:

$$C_{BAU}\,[€] = C_{LVnetwork}\,[€] + \mathrm{C_{Trafo}}\,[€]$$

It is worth mentioning that this is the costs calculated for the BAU solution at only one and unique point in the grid, while to have more realistic results, this number should be escalated, and multiplied by the number of points in the grid where these issues will arise in the future.

With this, it is safe to state the minimum cost of the FEVER technology, should have a maximum value equal to C_{BAU} for the DSO investment to be neutral.

On the side, the cost of the FEVER technology needs to be calculated, and this is the cost of all the new assets of the project (PEDs, batteries, FEMS, etc.). The sum of these costs, will give the total cost of the FEVER solution:

$$C_{FEVER}[€] = \mathrm{C_1}[€] + \mathrm{C_2}[€] + \mathrm{C_3}[€]$$

With these two total cost of the traditional and the FEVER set ups, the DSO investment variation can then be calculated as follows:

$$Investment\ variation\,[\%] = \frac{C_{BAU}}{C_{FEVER}}$$

$$DOA\_13[€] = C_{FEVER} - C_{BAU}$$

This part of the KPI aims at monitoring the operational costs (OPEX) associated to the FEVER technology and make sure they do not overcome the operational costs of a BAU solution. In order to compare OPEX of FEVER and the ones of a BAU solution, the following assumption needs to be made: if no technology exists, which can bring the same value of FEVER, the more similar device or solution will be considered.

When talking about the specific case of the Spanish pilot, it is worth mentioning that before 2021 the remuneration for the operation and maintenance, was stated in the Spanish rule in force until RD 1048/2013 + Order IET / 2660/2015. This differentiates between O&M of electrical assets (which is remunerated by unit value) and O&M of non-electrical assets (which is remunerated by invoice). The O&M amount of electrical assets ranges from 3% to 5% of the unit investment reference value.

An investment value of a usual new building of network assets at LV level including a secondary substation will be considered. Therefore, the O&M will be calculated as:

$$O\&M_{before21}\ [€/\text{year}] = \text{Investmet}\ [€] \cdot 4\%$$

Nevertheless, the new Spanish regulation (Circular 6/2019) which is already in fully force, eliminates the O&M remuneration directly linked to electrical assets and sets the remuneration for O&M, together with other concepts, within a new term called COMGES (Component Manageable of the Expense). This term is no longer indexed to the units of electrical assets owned and built. This is a type of salary, set based on the distribution history of each distributor and reviewed annually downwards, as it is to encourage the efficiency of the distributor.

4.4.14 DOA_14: Increase Power Quality

4.4.14.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Power quality: local supply voltage profiles: amount of time outside 5% of nominal	**HLUC02 HLUC07**	**UPC**	**ESP**

4.4.14.2 Calculation

The DOA_14 KPI will calculated based on the following equation:

$$DOA\_14 = t_{dev} = t_{+} + t_{-}\ [s]$$

Where,

t_+ is the amount of time during a week in which the voltage is higher than 1.05 p.u.

t_- is the amount of time during a week in which the voltage is lower than 0.95 p.u.

4.4.14.3 Observations

The bus with the highest voltage variation will be used for the calculation, since it is the worst case in the whole distribution grid. In order to compare the t_{dev} improvement, historical data can be used to evaluate before and after the implementation of voltage compensation strategies.

There is a risk involved in this KPI that is the possibility that the distribution grid under analysis do not have big voltage deviations, which means that t_{dev} would be equal to zero and no improvements can be measured.

4.4.15 DOA_18: CO2 emission reduction

4.4.15.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Percentage reduction in CO2 emissions (with respect to the values at the beginning of the project)	**Overreaching**	**Es-geht! (EST&UCY)**	**All**

Calculation

$$\boldsymbol{CO2\ Reduction\ for\ pilot\ X} = \frac{(CO_2^{Before\_x} - CO_2^{After\_X})}{CO_2^{Before\_X}}$$

Where X can represent the different pilots or their sum (SWW, SWH, ESP, CY).

$$\text{DOA\_18} \quad = \left(\mathbf{1} - \frac{\sum_{x\in\{\text{DE,ESP,CY}\}} CO_2^{After_x})}{\sum_{x\in\{\text{DE,ESP,CY}\}} CO_2^{Before_x}}\right) \times\ 100 \qquad [\%]$$

4.4.15.2 Observations

Calculation of CO2 footprint of the energy-mix at the pilots sites and changes over time starting with the status at the beginning of the project looking at the development course till the end of the pilot phase for the different pilot areas

- Spain: EST
- Germany: SWW, SWH
- Cyprus: UCY

4.4.16 DOA_19: Secure information and communication technologies

4.4.16.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the number of vulnerabilities detected in relevant scenarios to the solution	**Overreaching**	**ICOM**	**ALL**

4.4.16.2 Calculation

The Common Vulnerabilities and Exposures (CVE) list [6] will be used as a basis to detect possible vulnerabilities in the solution. Basic scenarios will be identified on the user of the system and the possible vulnerabilities will be scored based on a common vulnerability scoring system calculator [7]. Based on these scores, the total number of vulnerabilities will be populated.

4.4.17 DOA_20: Integration performance

4.4.17.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
This KPI is associated with several performance sub-indexes of the integration	**Overreaching**	**ICOM**	**ALL**

middleware: Throughput, Latency Time of completion Connectivity, Reuse

4.4.17.2 Calculation

- Throughput: Number of I/O transactions to the data repository of DSO Toolbox - flowing through the Integration Middleware (see D3.5);
- Latency: The time between when Integration Middleware (see D3.5) receives a request and when it returns the response. It will be measured on a request type basis;
- Time of completion: Percentage of processes where completion falls within +/- 5% of the estimated time completion. A baseline for each process will be calculated.
- Connectivity: Expresses the percentage of time where the different applications were connected to the middleware. This excludes downtime due to predicted maintenance.
- Reuse: Expresses the reusability of the processed developed in the middleware. Will be assessed via the number of authorised clients per process.

4.4.17.3 Observations

The following indexes will be constantly monitored during piloting: Throughput, Latency, Time of completion, Connectivity. On the contrary, Reuse metric will be calculated once, based on the authority assigned to the different users of the Integration Platform.

4.4.18 KPI_PUC01_1: Responsiveness of close to real-time prevention

4.4.18.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the time required for identifying the potential violation and proposing the mitigation actions in the close-to real time scenario.	**HLUC01**	**UdG, ICOM**	**DE,ESP**

4.4.18.2 Calculation

Detection or forecasting of critical events is done with data from field. The available record of data is dated at time t_a in seconds and together with previous observations, these data are used for forecasting possible critical events occurring at time t_o. Computation of critical event forecasting requires a time t_d-t_a. So, forecast is available at t_d; and at this time calculation of a mitigation strategy is calculated making if available for execution at t_m. Since the effective execution of the plan can take some additional time, the real execution occurs in t_e (cf. Figure 14). The time stamps are represented according to the standard of ISO 8601.

t_a: Time of the last available sample

t_d: Time instant when the possible critical event is detected

t_m: Time instant when the mitigation plan is ready for execution

t_o: Time instant when the occurrence of the critical event is expected to start.

t_e: Time instant when an existing order is being really executed (e.g. switchgear operation).

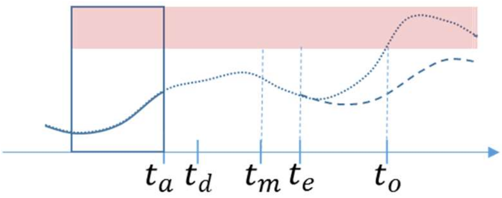

Figure 14:Timing for critical event mitigation

Thus, TTD is the time required to detect (or forecast the critical event) and TTM the time required to propose a mitigation plan after the detection (cf. Figure 14).

$$PUC01\_1a = TTD = t_d - t_a$$

$$PUC01\_1b = TTM = t_m - t_d$$

$TTD + TTM = t_m - t_a$, is the minimum time required to detect and calculate the mitigation plan.

4.4.18.3 Observations

- Computation of this KPI requires 1) detecting the possible critical event and 2) proposing the mitigation action. The first takes $t_d - t_a$ time and the second $t_m - t_d$
- Mitigation will be only possible when $t_d - t_o > TTM$.

4.4.19 KPI_PUC01_2: Performance of critical event forecasting

4.4.19.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
True positive, false positive (false alarms), true negative and false negative (missed detections) ratios of forecasted critical events.	**HLUC01**	**UdG, ICOM**	**DE,ESP**

4.4.19.2 Calculation

The critical event forecasting performance can be obtained as ratio of events predicted with respect to those really happening. These, the following are defined:

- **True Positive (TP)**: Critical event correctly forecasted/detected
- **True negative (TN)**: Absence of critical event correctly forecasted/detected as normal condition
- **False Positive (FP)**: A forecasted critical event that did not happen (**False Alarm or Type I error**)
- **False Negative (FN)**: A critical event not forecasted/detected (**Missed Detection or Type II error**)

Thus, the total of events forecasted (True) can be divided into TP and FP (false alarms); and analogously the system can miss to forecast a real event (missed detection or false negative). The possible combinations between relevant events and detected events are summarized in the following confusion table:

		Relevant events	
		True	False
Detected events	True	True positive (TP)	False positive (FP)
	False	False negative (FN)	True negative (TN)

Accuracy is a global indicator that can be calculated as a ration between right detections over the total number of observations:

$$Accuracy = \frac{TP + TN}{TP + TN + FN + FP}$$

Accuracy is not informative at all, since the ratio does not discriminate between True Positive and True negative events. So, other specific ratios are of interest:

- P*recision*, or PPV (Positive Predicted Value) which measures “how useful” the alarms (detection or forecasted events) are, can be calculated as a ration between true positives and the total of True detected events, through the following formula:

$$Precision = \frac{TP}{TP + FP}$$

- Re*call* or TPR (True Positive Rate), which measures “how complete” the results are, can be calculated through the following formula that measures the ration between true positives and the total of real True events:

$$TPR = \frac{TP}{TP + FN}$$

- *Missed detections* or FNR (False Negative Rate) [8] are measured as ratio of FN over the total of occurring events (FN+TP) and can be calculated through the following formula. Observe that Recall and missed detection ratios are complementary: TPR+FNR=1.

$$FNR = \frac{FN}{TP + FN}$$

- *False Alarms* can be represented by the False Positive Rate (FPR) or *fall out* computed as the ratio between false positive scores and the total number of observations in the category False.

$$FPR = \frac{FP}{FP + TN}$$

4.4.20 KPI_PUC02_1: Responsiveness of grid reconfiguration planning

4.4.20.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the time required for identifying the series of commands of grid switchgear	**HLUC01, HLUC04**	**UdG, ICOM**	**DE,ESP**

4.4.20.2 Calculation

Once a specific plan is available, its execution is not immediate, since it can be affected by many factors (e.g. validation by an operator, the refresh or cycle of the SCADA, communication delays, etc.). The, between the availability of a specific plan for switchgears at t_m, the final execution could be delayed until t_e being the difference the Time required To Execute a switchgear plan (TTE) (cf. Figure 14).

$$PUC02\_1 \quad = TTE = t_e - t_m$$

t_e: Time instant [seconds] when the switchgear command is really executed

t_m¨time when the switchgear plan is ready

The time stamps are represented according to standard ISO 8601.

2.1.1 KPI_PUC02_2: Efficiency of grid reconfiguration planning

4.4.20.3 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the amount of valid dispatches of the plan, with respect to the total requested.	HLUC01, HLUC04	UdG, ICOM	DE,ESP

4.4.20.4 Calculation

Given a reconfiguration plan, $GOP\ (j)$, represented as a sequence of N_j actions $GOP(j) = \{S_1, S_2, \ldots S_{N_j}\}$ and the number of valid dispatches in the plan L_j with $(L_j < N_j)$. The efficiency of this specific reconfiguration plan is defined by the ratio (L_j/N_j).Thus, the following indicator is defined as the Average of Efficiency of a reconfiguration plan (AERP) for the execution of M plans:

$$PUC02\_2 = AERP = \frac{1}{M}\sum_{j=1}^{M}\frac{L_j}{N_j}\,(x100) \qquad [\%]$$

4.4.21 KPI_PUC03_1: Amount of requested energy flexibility

4.4.21.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the total amount of energy deviation (∆kWh) requested by a flexibility service consumer (e.g., DSO, BRP).	HLUC01, HLUC05, HLUC08	INEA	DE,ESP,UCY

4.4.21.2 Calculation

The KPI is calculated as a summation of the requested energy from DSO on the daily, weekly and monthly level.

$$PUC03\_1 \quad = \sum_{i=1}^{N} E_{DSO\_request\_i},$$

Where

- *i* is hour of the day for the daily aggregation, day of the week of the weekly aggregation or day of the month for monthly aggregation
- *N* is 24 for daily aggregation, or 7 for weekly aggregation or number of days in the month for monthly aggregation
- $E_{DSO\_request\_i}$ is the requested energy in the time interval *i*.

The indicator is calculated separately for production and consumption.

4.4.22 KPI_PUC03_2: Amount of delivered energy flexibility

4.4.22.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the total amount of energy deviation (∆kWh) delivered in a response to a flexibility request	HLUC01, HLUC05, HLUC08	INEA	DE,ESP,CY

4.4.22.2 Calculation

The KPI is calculated as a summation of the assigned energy by all prosumers on DSO request on the daily, weekly and monthly level.

$$PUC03\_2 = \sum_{i=1}^{N} E_{DSO\_assigned\_i}$$

Where

- *i* is hour of the day for the daily aggregation, day of the week of the weekly aggregation or day of the month for monthly aggregation
- *N* is 24 for daily aggregation, or 7 for weekly aggregation or number of days in the month for monthly aggregation
- $E_{DSO\_assignedt\_i}$ is the DSO assigned energy in the time interval *i*.

The indicator is calculated separately for production and consumption.

4.4.23 KPI_PUC03_3: Total flexibility request cost

4.4.23.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the total flexibility service consumer (e.g., DSO, BRP) cost incurred for requesting flexibility services	**HLUC01, HLUC05, HLUC08**	**INEA**	**DE,ESP,CY**

4.4.23.2 Calculation

The KPI is calculated as a summation of the assigned prosumer energies multiplied by price from DSO on the daily, weekly and monthly level.

$$PUC03\_3 = \sum_{prosumer} \sum_{i=1}^{N} p_i * E_{assigned\_i}$$

where

- *i* is hour of the day for the daily aggregation, day of the week of the weekly aggregation or day of the month for monthly aggregation.
- *N* is 24 for daily aggregation, or 7 for weekly aggregation or number of days in the month for monthly aggregation.
- $E_{ssignedt\_i}$ is the prosumer's assigned energy in the time interval *i*.
- p_i is price of the energy in the time interval *i*

The indicator is calculated separately for production and consumption.

4.4.24 KPI_PUC04_1: Amount of offered energy flexibility

4.4.24.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the total amount of energy flexibility (ΔkWh) offered by the flexibility service provider.	**HLUC04, HLUC05, HLUC06, HLUC08, HLUC09, HLUC12, HLUC13, HLUC14**	**INEA**	**DE,ESP,CY**

4.4.24.2 Calculation

The KPI is calculated as a summation of the offered energy from prosumer on the daily, weekly and monthly level.

$$PUC04\_1 = \sum_{i=1}^{N} E_{offered\_i}$$

where

- i is hour of the day for the daily aggregation, day of the week of the weekly aggregation or day of the month for monthly aggregation.
- N is 24 for daily aggregation, or 7 for weekly aggregation or number of days in the month for monthly aggregation.
- $E_{offered\_i}$ is the prosumer's offered energy in the time interval i.

The indicator is calculated separately for production and consumption.

4.4.25 KPI_PUC04_2: Amount of delivered energy flexibility

4.4.25.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the total amount of energy flexibility (ΔkWh) delivered by the flexibility service provider.	**HLUC04, HLUC05, HLUC06, HLUC08, HLUC09, HLUC12, HLUC13, HLUC14**	**INEA**	**DE,ESP,CY**

4.4.25.2 Calculation

The KPI is calculated as a summation of the assigned energy by individual prosumers on DSO request on the daily, weekly and monthly level.

$$PUC04\_2 = \sum_{i=1}^{N} E_{assigned\_i}$$

where

- i is hour of the day for the daily aggregation, day of the week of the weekly aggregation or day of the month for monthly aggregation.
- N is 24 for daily aggregation, or 7 for weekly aggregation or number of days in the month for monthly aggregation.
- $E_{asigned\_i}$ is the prosumer's assigned energy in the time interval i.
- p_i is price of the energy in the time interval i

The indicator is calculated separately for production and consumption.

4.4.26 KPI_PUC04_3: Total reward

4.4.26.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses total reward obtained for issuing flexibility services.	**HLUC04, HLUC05, HLUC06, HLUC08, HLUC09, HLUC12, HLUC13, HLUC14**	**INEA**	**DE,ESP,CY**

4.4.26.2 Calculation

The KPI is calculated as a summation of the assigned energy of the individual prosumer multiplied by price on the daily, weekly and monthly level.

$$PUC04\_3 = \sum_{i=1}^{N} p_i * E_{assigned\_i}$$

where

- *i* is hour of the day for the daily aggregation, day of the week of the weekly aggregation or day of the month for monthly aggregation.
- *N* is 24 for daily aggregation, or 7 for weekly aggregation or number of days in the month for monthly aggregation.
- $E_{asigned\_i}$ is the prosumer's assigned energy in the time interval *i*.
- p_i is price of the energy in the time interval *i*

4.4.27 KPI_PUC05_1: Prosumer reliability

4.4.27.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Describes how well certain flexibility providers deliver the traded flexibility	HLUC01, HLUC04, HLUC05, HLUC06, HLUC08, HLUC09, HLUC12, HLUC13, HLUC14, HLUC15	**INEA**	**DE,ESP,CY**

4.4.27.2 Calculation

The KPI is calculated as a ratio between realized energy and assigned energy:

$$PUC05\_1 = \frac{ABS(E_{realized})}{ABS(E_{assigned})}$$

Where

- $E_{realized}$ is a difference between measured consumption/production and default operation with no intervention
- $E_{assigned}$ is assigned deviation from default operation.

Since the energy may be of both signes the abs value must be used. The KPI is calculated on the daily, weekly and monthly level.

4.4.28 KPI_PUC06_1: Congestion management effectiveness

4.4.28.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Average efficiency of congestion management actions.	**HLUC01, HLUC02, HLUC04, HLUC06**	**UdG, ICOM**	**DE,ESP**

4.4.28.2 Calculation

A congestion is defined as an excess of current (I), over a threshold, I_{th}, in a specific asset (e.g transformer, line segment).

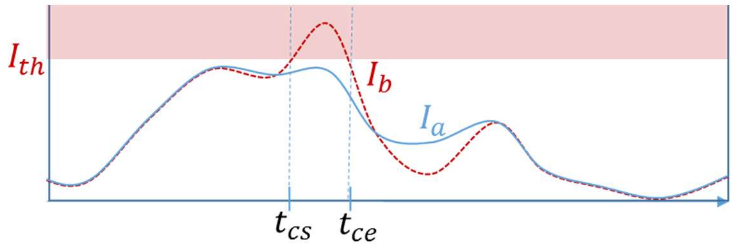

Figure 15: Congestion (red)

With:

I_b: Current before the application of a mitigation action

I_a: Current after the application of a mitigation action

I_{th}: Maximum current admissible

t_{cs}: Congestion starting time

t_{cs}: Congestion ending time

Thus, a congestion implies $\frac{I}{I_{th}} > 1$ during a certain time interval $\Delta t = t_{ce} - t_{cs}$. A simple way of characterizing the congestion is taken the maximum value in the interval ($I_{\max}$) or its relative value respect to the threshold $\frac{I_{\max}}{I_{th}}$.

Based on this definition two possible measures of effectiveness can be defined: reduction of current in the asset and reduction in the duration of the congestion time.

A) Individual effectiveness indicators

Individual (single congestion) Effectiveness of Congestion management in Magnitude (ECM) can be computed simply comparing the poorest situation before and after the application of the mitigation action with respect to the congestion threshold:

$$ECM = \frac{I_{\max\_b} - I_{\max\_a}}{I_{th}} \, (x100) \qquad [\%]$$

Being $I_{\max} = \max\{I(t)\}$ for $t_{cs} \leq t \leq t_{ce}$; and the subindices *a* and *b* indicate before and after the mitigation action. And a congestion is avoided when $I_{\max\_a} \leq I_{\text{th}}$, or in terms of ECM when $ECM \geq \frac{I_{\max\_b}}{I_{th}} - 1$

Individual (single congestion) Effectiveness of Congestion management in Time (ECT):

$$ECT = \frac{\Delta t_b - \Delta t_a}{\Delta t_b} \, (x100) \qquad [\%]$$

In that case the congestion is avoided if $\Delta t_a = 0$ ($ECT = 1$).

Global effectiveness indicators (campaign):

And from previous, a set of global, or summary, index for a specific campaign involving the management of M_T congestions can be obtained:

B) Average of effectiveness of congestion management in magnitude:

$$AECM = \frac{1}{M_T} \sum_{j=1}^{M} ECM_j \qquad [\%]$$

C) Average of effectiveness of congestion management in time:

$$AECT = \frac{1}{M_T}\sum_{j=1}^{M} ECT_j \qquad [\%]$$

D) Percentage of avoided congestions:

$$PAC = \frac{M_{AC}}{M_T}\,(x100) \qquad [\%]$$

With:

M_{AC}: Number of avoided congestions ($ECT = 1$ or $\geq \frac{I_{\max\_b}}{I_{th}} - 1$)

M_T: Total number of congestion to be avoided

4.4.28.3 Observations

$I_{\max\_b}$ is always an estimation made before the occurrence of the congestion and consequently it cannot be measured.

$I_{\max\_a}$ could be either an estimation or a measured value. The first is obtained as a result of the calculation of the mitigation plan; so it could available before applying the solution; the second is the real measured value during the time when the congestion was expected.

4.4.29 KPI_PUC06_2: Voltage compensation effectiveness

4.4.29.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Average efficiency of voltage compensation actions.	**HLUC01, HLUC02, HLUC04, HLUC06**	**UdG, UPC, ICOM**	**DE,ESP**

4.4.29.2 Calculation

Refer to KPI_PUC06_1 (replacing I by V), resulting in the following equivalent expressions:

A) Individual Effectiveness of Voltage compensation action in Magnitude (EVM) can be computed with the following expression

$$EVM = \frac{|V_{m\_b} - V_{m\_a}|}{V_{th}}\,(x100) \qquad [\%]$$

Where

V_{m_b} and V_{m_a} represent the maximum (or minimum) voltage during an overvoltage (or undervoltage) event and V_{th} is the threshold for that situation; and the subindices *a* and *b* indicate before and after the mitigation action. And a congestion is avoided when $V_{m\_a} \leq V_{th}$ for an overvoltage and $V_{m\_a} \geq V_{th}$ for a subvoltage event.

Individual (single congestion) Effectiveness of Voltage action in Time (EVT):

$$EVT = \frac{\Delta t_b - \Delta t_a}{\Delta t_b}\,(x100) \qquad [\%]$$

In that case the congestion is avoided if $\Delta t_a = 0$ ($EVT = 1$).

Global effectiveness indicators (campaign):

And from previous, a set of global, or summary, index for a specific campaign involving the management of M_T voltage events can be obtained:

B) Average of effectiveness of congestion management in magnitude:

$$AEVM = \frac{1}{M_T}\sum_{j=1}^{M} EVM_j \qquad [\%]$$

C) Average of effectiveness of congestion management in time:

$$AEVT = \frac{1}{M_T}\sum_{j=1}^{M} EVT_j \qquad [\%]$$

D) Percentage of Avoided Voltage events:

$$PAV = \frac{M_{AV}}{M_T}\,(x100) \qquad [\%]$$

With:

M_{AV}: Number of avoided voltage events ($EVT = 1$)

M_T: Total number of voltage events to be avoided

4.4.30 KPI_PUC06_3: Loss compensation effectiveness

4.4.30.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Average efficiency of technical loss reduction actions.	**HLUC01, HLUC02, HLUC04, HLUC06**	**UdG**	**DE,ESP**

4.4.30.2 Calculation

See KPI_PUC13_1: Loss reduction.

4.4.31 KPI_PUC06_4: Self-healing effectiveness

4.4.31.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Average efficiency of self-healing reduction actions.	**HLUC01, HLUC02, HLUC04, HLUC06**	**UdG, UP, ICOM**	**DE,ESP**

4.4.31.2 Calculation

Objective of self-healing is to increase reliability of the grid and reduce affectation of customers due to faults or misbehaviors occurring in in the grid. Under this perspective effectiveness of self-healing can be computed in terms of duration and number of affectations in a similar way as KPI_PUC29_04 where SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency

Index) but focusing the indicator on effectiveness of every self-healing action and then computing the average effectiveness of a set of actions during a campaign where the mitigation action is implemented.

Reduction of number affected customers (per customer): [%]

$$PUC06\_4a = \frac{\Delta N}{N_T} = \frac{N_b - N_a}{N_T}\ (x100)$$

N_b

N_b:: Total Number of Customers affected before applying self healing action: $\sum N_{b\_i}$

N_a: Total Number of Customers affected after applying the self healing action: $\sum N_{a\_i}$

N_T: Total Number of Customers in the area

Reduction of affectation time (per customer): [%]

$$PUC06\_4b = \frac{\Delta T}{N_T} = r_i \frac{\Delta N}{N_T} = r_i \frac{N_b - N_a}{N_T}\ (x100)$$

Where:

r_i: is the self-healing actuation time in minutes

Average values can be computed by considering several self-healing actuation in a specific period or campaign.

4.4.32 KPI_PUC06_5: Faulty feeder detection accuracy

4.4.32.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the forecast accuracy of the faulty feeder.	**HLUC01, HLUC02, HLUC04, HLUC06**	**UdG, UP, ICOM**	**DE,ESP**

4.4.32.2 Calculation

See PUC01_2: Performance of critical event forecasting

Explanation of calculation [8]:

The objective of the fault detection tool is to detect the faults occurring in the distribution grid. Hence, it is necessary to quantify the performance of the tool by calculating its accuracy regarding the detection of faulty feeders. For this reason, a standard metric for classification problems is leveraged, namely F1 score. [9]

$$PUC06\_5 = Faulty\ feeder = 2 * \frac{(precision * recall)}{(precision + recall)}$$

where:

$precision = \frac{t_p}{t_p + f_p}$

$recall = \frac{t_p}{t_p + f_n}$

t_p= the number of true positive detections,

t_n=the number of true negatives,

f_p and f_n the number of false positive and negative detections

4.4.33 KPI_PUC06_6: Faulty branch identification accuracy

4.4.33.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the forecast accuracy of the faulty branch.	**HLUC01, HLUC02, HLUC04, HLUC06**	**UdG, UP, ICOM**	**DE,ESP**

4.4.33.2 Calculation

Explanation of calculation [8]:

For the faulty branch identification, while it is also a classification problem, the resulting metrics are slightly different, compared to the fault feeder detection. In particular, the goal is to identify which of the grid branches is the one where the fault has occurred (the occurrence of the fault itself was already detected in the previous task). [10]

$$PUC06\_6 \quad = Faulty\ branch = \frac{t_p}{(t_p + f_n)}$$

Where:

t_p = the number of times a branch is correctly identified as faulty

f_n = the number of times a branch wrongly identified as healthy

4.4.34 KPI_PUC06_7: Distance error of fault detection

4.4.34.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the distance error between the actual location of the fault and the predicted one.	**HLUC01, HLUC02, HLUC04, HLUC06**	**UdG, UP, ICOM**	**DE,ESP**

4.4.34.2 Calculation

Since the location of the fault is provided as the distance of that location from the beginning of the branch, the accuracy of the method is evaluated in terms of standard fault distance estimation error. [11]

$$PUC06\_7 = d_{error} = \left[\frac{(|d_{est} - d_{actual}|)}{total}\right] \times 100\%$$

Where

d_{est} = predicted fault location in the branch

d_{actual} = actual fault location in the branch

$total$ = Total distance of the line

Is calculated in [m].

4.4.35 KPI_PUC07_1: Responsiveness of close-to real time prevention

4.4.35.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the time required for identifying the potential violation and proposing the mitigation actions.	**HLUC02**	**UPC**	**DE, ESP**

Already defined in KPI_PUC01_1

4.4.36 KPI_PUC08_1: Islands detected

4.4.36.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the percentage of successful island detections.	**HLUC03**	**UPC**	**DE, ESP**

4.4.36.2 Calculation

The usage of this KPI relies heavily on the amount of events occurring, hence the percentage. For incredible rare events such as unintended islanding it might be necessary to adopt different ways to measure the performance of island detection. A proposal would be to have a forced islanding scenarios (laboratory testing, field testing etc.) where half of them would have the IPMA detection algorithm while the other half not.

$$PUC08\_1 = D_{ipma}[\%] - D_{no\_ipma}[\%]$$

where,

$$D_{ipma}[\%] = \frac{D_{ipma}}{SC_{ipma}} \times 100$$

$$D_{no\_ipma}[\%] = \frac{D_{no\_ipma}}{SC_{no\_ipma}} \times 100$$

- ***D*** represents the total number of cases in which the unintended island was detected and ***SC*** the total number of cases tested. In the end is expected a positive value of KPI_PUC_08_1 indicating an improvement in the island detection.

4.4.36.3 Observations

The total amount of scenarios must be equal for both cases, with and without IPMA.

$$SC_{no\_ipma} = SC_{ipma}$$

4.4.37 KPI_PUC09_01: Responsiveness of close-to real time mitigation

4.4.37.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the time required for de-energizing the uncontrolled island after the mitigation request.	**HLUC03**	**UPC**	**DE,ESP**

Already defined in KPI_PUC01_1

4.4.38 KPI_PUC09_02: Islands mitigated

4.4.38.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the percentage of successfully mitigated uncontrolled islanding situation problems	**HLUC03**	**UPC**	**DE, ESP**

4.4.38.2 Calculation

Following the definitions made in KPI_PUC_08_1, percentage of islands mitigated will be:

$$PUC09\_02 = \frac{M}{D_{ipma}} \times 100\ [\%]$$

Where ***M*** is the total number of cases in which the unintended island was detected and mitigated

Observations

$$M \leq D_{ipma}$$

4.4.39 KPI_PUC10_1: Power Quality Indicator

4.4.39.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the percentage of successful detection of power quality requirement violations.	**HLUC07**	**UPC**	**ESP**

4.4.39.2 Calculation

The power quality violations detection evaluates the harmonic distortion and phase unbalances, which are calculated using the following equations.

$$THD_V = \frac{\sqrt{\sum_{h=2}^{\infty} V_{h,rms}^2}}{V_{f,rms}}$$

$$VUF\ [\%] = \frac{|V_2|}{|V_1|} \times 100\ [\%]$$

A violation is detected when any of these parameters are higher than the maximum established by the standard EN 50160:

$$THD_V \ \leq 5\%$$

$$VUF\ [\%] \leq 2\%$$

KPI_PUC10_1 is then calculated as the amount of time under the above circumstances while operating with ($t1_{dev}$) and without (t_{dev}) the PQS mitigation strategy.

$$PUC10\_1 = \frac{t1_{dev}}{t_{dev}} \times 100\ [\%]$$

4.4.39.3 **Observations**

In order to compare the t_{dev} improvement, historical data can be used to evaluate before and after the implementation of power quality enhancement strategies.

There is a risk involved in this KPI that is the possibility that the distribution grid under analysis do not have big power quality issues, which means that $t1_{dev}$ would be equal to zero and no improvements can be measured.

4.4.40 KPI_PUC11_01: Improvement of power quality

4.4.40.1 **Overview**

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the reduction of losses due to reduction of harmonics and reduction of imbalances in presence of lack of power quality.	**HLUC07**	**UPC**	**ESP**

4.4.40.2 **Calculation**

The test is based on the real measurement of the current reduction of the three phases in the pilot area of reference. It is important to note that the measurements should be taken with two identical power quality analyzers (e.g. two PQMs), installed upstream and downstream the PCC of the PED. The KPI_PUC11_01 is a percent value of losses reduction. The following equation shows that the electrical losses (P_{losses}) are proportional to the product of conductor resistance or the system equivalent resistance (R_{eq}) and the square of the total current (I_T).

$$P_{losses} = R_{eq} \cdot I_t^2$$

Therefore, it is assumed that for both situations (with and without PED contribution) the equivalent resistance is the same.

$$PUC11\_01 = \frac{I_{T\,upstream}^2}{I_{T\,downstream}^2} x\ 100\ \%$$

Where the total current (I_T) is the RMS value of all harmonic contributions (I_n) up to the 15th order:

$$I_T = \sqrt{\sum_{n=1}^{15} I_n}$$

4.4.40.3 Observations

The calculation is made for the three phases individually, in order to consider the effects of system unbalances as well.

4.4.41 KPI_PUC12_1: Responsiveness of self-healing

4.4.41.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the time required for identifying the fault and proposing the mitigation actions.	**HLUC04**	**UdG, ICOM**	**DE,ESP**

4.4.41.2 Calculation

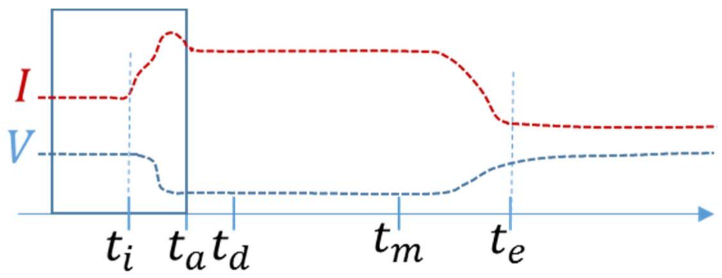

Figure 16: Fault time diagram from fault occurrence to execution of mitigation plan

The following times are defined:

t_a: Fault inception time

t_a: Acquisition time

t_d: Fault detection time

t_m: Time instant when the mitigation plan is ready for execution

t_e: Fault extinction time (When the plan is being executed): **(I recovers a steady state)**

Time stamps are represented according to standard ISO 8601.

Time units (for operations): seconds

And form them, the following indicators can be defined:

Time required to identify the fault (TTI):

$$TTI = t_d - t_i$$

Time required to propose a mitigation plan (TTM):

$$TTM = t_m - t_d$$

Time required to extinguish the fault (TTE):

$$TTE = t_e - t_i$$

4.4.42 KPI_PUC13_1: Loss reduction

4.4.42.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Percentage of loss reduction w.r.t BAU.	**HLUC06**	**UdG**	**DE,ESP**

4.4.42.2 Calculation

This KPI aims to measure how technical losses can be reduced by reducing energy exchange with the main grid at substation level.

Three sub-indicators, can be calculated:

- The reduction of transport losses due to a reduction of imported energy, through improved energy management;
- The reduction of exported energy in proportion to the energy generated;
- The reduction of power peaks.

Description follows below:

A) **Loss reduction due to reduction of imported energy:** When the consumption is higher than generation the secondary distribution network is importing energy and $E_p(i) > 0$. The imported energy during the window of time $[0, T]$ is

$$\text{Imported Energy} = \sum_{\substack{i=1 \\ \text{s.t. } E_p>0}}^{i=T} E_p(i)$$

This term is assumed to be proportional to the main losses of the network associated to the transmission and distribution lines ($\text{Losses T\&D} \propto \text{Imported Energy}$)

The change amount of imported energy IE thanks to FEVER with respect to BAU (IE_{BAU}) at substation, or interconnection level, can then give us a rough approximation about the impact of these factors.

$$\Delta IE = \frac{\text{IE} - \text{IE}_{BAU}}{\text{IE}_{BAU}} (x100) \quad [\%]$$

B) **Loss reduction due to reduction of exported energy:** When $E_p(i) < 0$ the generation exceeds the amount of demand and the exceeding energy is exported upstream of the substation. The energy generated within the grid can also be evaluated.

$$\text{Exported Energy} = \sum_{\substack{i=0 \\ \text{s.t. } E_p<0}}^{i=T} E_p(i)$$

$$\text{Produced Energy} = \sum_{i=0}^{i=T} E_G(i)$$

We consider the difference with the amount of produced energy (PE) in the grid and the exported (EE) associated to the amount of locally generated energy use.

$$\text{Locally generated energy use} = \frac{\text{PE} - \text{EE}}{\text{PE}}$$

Therefore, the relative change in exported energy caused by FEVER is directly related to the amount of energy locally consumed.

$$\Delta\text{EE} = \frac{\text{EE}_{\text{BAU}} - \text{EE}}{\text{EE}_{\text{BAU}}} (x100) \quad [\%]$$

4.4.42.3 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the percentage of target SoC reached.	**HLUC06, HLUC13**	**UPC, INEA**	**DE,ESP**

Calculation

The EV chargers (EVSE) together with the local EMS will charge or discharge the EV based on the desired SoC and the provision of flexibility. The KPI_PUC22_01 express the percentage of SoC that was reached considering the flexibility services provided:

$$PUC22\_01 = \frac{SoC_{reached}}{SoC_{scheduled}} [\%]$$

In an ideal situation the provision of flexibility will not affect the final SoC scheduled by the EV, but only the charging and discharging schedule, either providing time or energy flexibility to be traded in the FTP.

4.4.42.4 Observations

The calculation is made for each individual EV, starting from an initial SoC at the time of the EV is connected to the EVSE and the final SoC reached at the moment of disconnection.

4.4.43 KPI_PUC22_02: Economic benefit of using FEVER EV charging

4.4.43.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the economic benefit of using FEVER EV charging.	**HLUC06, HLUC13**	**UPC, INEA**	**DE,ESP**

4.4.43.2 Calculation

EV users gain economic benefit provisioning flexibility at EVSE chargers. KPI_PUC22_02 expresses the charging cost reduction at regular usage of the flexible charging station. The KPI is calculated as

$$PUC22\_02 = \frac{flex\_gain_{measured}}{charging\_cost} [\%].$$

The “flex_gain” as calculated as a product of the flexibility price offered by prosumer and amount of realized time shift measured by the flexibility system. The charging cost is calculated as net amount of electricity drawn from the grid multiplied the retailer price.

4.4.43.3 Observations

The calculation is provided by FTP for the individual prosumer. It is calculated on the individual charging event and aggregated intervals like daily, weekly.

4.4.44 KPI_PUC27_01: Daily Number of interventions

4.4.44.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Daily Number of interventions	**HLUC13**	**SWW**	**DE,ESP**

4.4.44.2 Calculation

The number of interventions within 24 h (X_i) to compensate for deviations from planning will be summed up.

$$PUC27\_01 = Number\ of\ interventions = \sum_{i=1}^{y} X_i$$

4.4.44.3 Observations

The energy amount should be monitored.

4.4.45 KPI_PUC27_02: Amount of needed energy flexibility

4.4.45.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Amount of needed energy flexibility	**HLUC13**	**SWW**	**DE,ESP**

4.4.45.2 Calculation

The amount of energy flexibility needed (Flexi_E) by the BRP management system over a given period of time (e.g. day or month). This shall be done with aid of the values calculated in KPI_PUC27_1 with relations to the energy amounts (E_i).

$$PUC27\_02 = (\mathrm{Flexi_E}) = \sum_{i=1}^{y} X_i \times E_i$$

4.4.46 KPI_PUC27_03: External procurement

4.4.46.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
External procurement	**HLUC13**	**SWW**	**DE,ESP**

See KPI_PUC27_1: Daily Number of Interventions

4.4.47 KPI_PUC29_01: Critical loads connectivity

4.4.47.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Critical loads which need to remain connected in islanding operation.	**HLUC05**	**UCY**	**CY**

4.4.47.2 Calculation

Critical loads where supply must be ensured in islanding operation. The KPI will be calculated as the percentage of critical loads which remain connected:

$$PUC29\_01 = \frac{CL_{Connected}}{CL_{Total}} \times 100\ [\%]$$

Where CL is the sum of power, energy or number of critical loads (connected or in total).

4.4.48 KPI_PUC29_02: Frequency regulation

4.4.48.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Frequency to be retained within limits in islanding operation.	**HLUC05**	**UCY**	**CY**

4.4.48.2 Calculation

The frequency of the microgrid in islanding mode needs to be retained within the required limits which are imposed by the grid code. Two formulas are used.

$$\Delta f \rightarrow \varepsilon$$

$$PUC29\_02 = RoCoF(t) = \frac{df(t)}{dt} < 1.7Hz/s$$

Where f is the frequency and $RoCoF$ is the Rate of Change of Frequency.

4.4.49 KPI_PUC29_03: Voltage regulation

4.4.49.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Voltage to be retained within limits in islanding operation.	**HLUC05**	**UCY**	**CY**

4.4.49.2 Calculation

The voltage of the microgrid in islanding mode needs to be retained within the required limits, which are imposed by the grid code.

$$\Delta V \rightarrow \varepsilon$$

The 95% of the 10-minute mean rms values of a week should be within a ±10% of the nominal voltage. The entirety of the mean rms values of the week should be within +10% / -15% of nominal voltage.

According to the defined EN 50160 Standards (this refers to non-islanding circumstances however there is no standard referring to islanding operation), bus bar voltage magnitudes must comply with the aforementioned allowed range of variation.

4.4.50 KPI_PUC29_04: Power supply continuity

4.4.50.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the continuous supply of power to customers' loads in islanding operation.	**HLUC05**	**UCY**	**CY**

4.4.50.2 Calculation

System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) indices will be measured under the prism of a Major Event Day (MED):

$$SAIFI = \frac{Total\ Number\ of\ Customers\ Interrupted}{Total\ Number\ of\ Customers\ Served} = \frac{\sum N_i}{N_T}$$

$$SAIDI = \frac{Total\ minutes\ of\ all\ customer\ interruption\ durations}{Total\ Number\ of\ Customers\ Served} = \frac{\sum r_i * N_i}{N_T}$$

where r_i is the restoration time in minutes, N_i is the total number of customers interrupted and N_T is the total number of customers served.

In addition, the MED threshold (TMED) will have to be calculated using the following equation:

$$T_{MED} = e^{(\alpha+2.5\beta)}$$

where α is the log-average of all daily SAIDI values and β is the log-standard deviation of all daily SAIDI values.

4.4.51 KPI_PUC29_05: Flexible loads

4.4.51.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the number of flexible loads available in the pilot area.	**HLUC05, HLUC08**	**UCY**	**CY**

4.4.51.2 Calculation

Percentage of flexible loads to total loads in the pilot area. The percentage can be computed in either by Capacity of loads or Energy.

4.4.52 KPI_PUC29_06: Trading flexibility

4.4.52.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Number of flexible loads implemented for trading flexibility.	**HLUC05, HLUC08**	**UCY**	**CY**

4.4.52.2 Calculation

Evaluation of the DER utilization for ancillary services (UAS) or other flexibility products. This KPI is expressed by the ratio between the energy used for ancillary services and other flexible load operations requested by the market (EASE) and the total energy produced (TEP).

$$PUC29\_06 = UAS = \frac{EASE}{TEP} \times 100 \quad (\%)$$

4.4.53 KPI_PUC29_07: Operation cost

4.4.53.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Change of operation cost due to the management and trade of flexibility.	**HLUC08**	**UCY**	**CY**

4.4.53.2 Calculation

From the aggregator point of view, operation cost with management and trade of flexibility is larger than operation cost without the presence of flexibility.

$$PUC29\_07 = OpCostFl = OpCost + FlCost$$

$$ReFl - FlCost > 0$$

where $OpCostFl$ is the operating cost of the aggregator including flexibility costs ($FlCost$) which are added to the business as usual (BAU) operating costs ($OpCost$). Revenues from trading flexibility ($ReFl$) should cover the extra costs required for operation.

4.4.54 KPI_PUC31_1: External Procurement

4.4.54.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Internal prioritization of own generation, storage and flexibility depending on price signals; External procurement below the specified value	**HLUC14**	**SWW/SWH**	**DE**

4.4.54.2 Calculation

The "clean" electricity prices, i.e. prices of generation/feed-in without any end-price breakdown elements such as transport and grid usage costs, shall be determined. The next step will involve identifying the local energy mix and calculating its “clean” price. This price then will be compared with the prices at the electricity exchange market.

$PV \ = \ A\ ct/kWh$

$BESS \ = \ B\ ct/kWh$

$Wind \ = \ C\ ct/kWh$

$CHP \ = \ D\ ct/kWh$

$Other \ = \ E\ ct/kWh$

$[PV + BESS + Wind + CHP + \cdots] = Energy\ mix$

$$Extern\ Electrcitiy\ Price \ \geq Local\ Electricity\ Price$$

$$Extern\ Electrcitiy\ Price \ \geq \sum X\ [PV + BESS + Wind + CHP + \cdots]$$

The external electricity price is calculated depending on the power plant type and producer, or by EEX. This factor is necessary for the calculation which is used here to show that as long as the local price is lower or equal to the external one, the local one is favourited leading to a prioritisation of the local electricity generation.

4.4.54.3 Observations

As long as the local electricity mix, considering only production costs without any grid fees, cheaper or more lucrative than the electricity mix sold on the electricity market, the local production will be prioritized.

Furthermore, this requirement needs to be applicable to the LECs once they are established.

4.4.55 KPI_PUC32_01: Transaction processing throughput

4.4.55.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses the throughput of transaction processed by the platform. The platform should be scalable and able to process high throughput of these (at least 5 per second), incurred by different peers.	**HLUC15**	**FLEX**	**DE**

4.4.55.2 Calculation

This KPI is to be measured for a particular energy community (EC), by counting a number of transactions incurred by peers (peer agents) within a selected time period. This KPI concerns different types of transactions: 1) FlexCoin (pseudo-currency) transactions per second, 2) flexibility trading transactions (FlexTrading DAPP).

4.4.55.3 Observations

This KPI will be monitored by P2P-FTP and displayed to admin and EC-Operators users in the GUI.

4.4.56 KPI_PUC32_02: Number of peers

4.4.56.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Number of peers that are actively participating in the peer to peer trading, by requesting and offering flexibilities.	**HLUC15**	**FLEX**	**DE**

4.4.56.2 Calculation

This KPI is to be measured for a particular energy community (EC), by counting a number of active peers. An active peer is the one having an access to the platform (P2P-FTP) and issued at least 1 (authorization, pseudo-currency, or flexibility trading) transaction within the last 1 month.

4.4.56.3 Observations

This KPI will be monitored by P2P-FTP and displayed to admin and EC-Operators users in the GUI, and compared to the total number of EC peers registered in the platform.

4.4.57 KPI_SUC01_1: Performance of forecasting

4.4.57.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Accuracy of the forecasting: Mean absolute percentage error (MAPE)	**HLUC01, HLUC02 HLUC04, HLUC05, HLUC08**	**UdG, UCY**	**DE,CY,ESP**

4.4.57.2 Calculation

Consider the problem of forecasting a magnitude $E(t)$, (e.g. energy demand or generation) by using a function of a set of known variables $\hat{E}(t) = f(X)$. The difference between the real value and the output of this function is the prediction error $E(t) - \hat{E}(t)$. The **Mean Absolute Prediction Error** for a set of pairs M pairs $(E(t), \hat{E}(t))$ is calculated as follows:

$$SUC01\_1a = MAPE = \frac{1}{M}\sum_{t=1}^{M}\left|E(t) - \hat{E}(t)\right|$$

The **Root Mean Square Error** (RMSE) is the standard deviation of the residuals (prediction errors). The RMSE of predicted values $\hat{E}(t)$ for times M of a regression's dependent variable $E(t)$ with variables observed over M times, is computed for n different predictions as the square root of the mean of the squares of the deviations. The RMSE of an estimator $\hat{E}(t)$ with respect to an estimated parameter $E(t)$ is defined as the square root of the mean square error:

$$SUC01\_1b = RMSE = \sqrt{\frac{1}{M}\cdot\sum_{i=1}^{M}(\hat{E}(t) - E(t))^2}$$

4.4.58 KPI_SUC02_1: Data received

4.4.58.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Percentage of data received vs expected per time period.	**HLUC01, HLUC02, HLUC03, HLUC04, HLUC06, HLUC07**	**UPC, ICOM**	**DE,CY,ESP**

4.4.58.2 Calculation

Expected Measurements: Number of measurements expected in a specified period of time (e.g. day). For fixed granularity measurement it will be calculated. For variable granularity an average value will be calculated.

Received Measurements: Number of measurements actually received for a specified period of time

$$\text{SUC02\_1} = \frac{\text{Received Measurements}}{\text{Expected Mesurements}} \text{ x } 100$$

4.4.58.3 Observations

Received measurement will be considered all measurements that refer to the period of interest.

4.4.59 KPI_SUC02_2: Availability of data received

4.4.59.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Percentage of data received in expected refreshing period.	**HLUC01, HLUC02, HLUC03, HLUC04, HLUC06, HLUC07**	**UPC, ICOM**	**DE,CY,ESP**

4.4.59.2 Calculation

Expected Measurements: Number of measurements expected in a specified time window(e.g. day). For fixed granularity measurement it will be calculated. For variable granularity an average value will be calculated.

Received Measurements: Number of measurements actually during in a specified period of time, based on the time received.

$$\text{SUC02\_2} \quad = \frac{\text{Received Measurements}}{\text{Expected Mesurement}}$$

4.4.59.3 Observations

Received measurement will be considered all measurements that refer to the period of interest and were received in the specified time window. On the contrary for the previous index, KPI^{SUC02_1}, all measurements will be considered, regardless to the time received.

4.4.60 KPI_SUC02_3: Consistency of data received

4.4.60.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Percentage of consistent data	**HLUC01, HLUC02, HLUC03, HLUC04, HLUC06, HLUC07**	**UPC, ICOM**	**DE,CY,ESP**

4.4.60.2 Calculation

Outliers : Number of data with NA value or outside specified boundaries in a specified period of time (e.g. day).

Expected Measurements: Number of measurements expected in a specified period of time (e.g. day). For fixed granularity measurement it will be calculated. For variable granularity an average value will be calculated.

Received Measurements: Number of measurements actually during in a specified period of time, based on the time received.

Missing Measurements = Expected Measurements - Received Measurements

$$SUC02\_3 = 1 - \frac{\text{Outliers} + \text{Missing Measurement}}{\text{Expected Mesurements}} = \frac{\text{Outliers} + \text{Received Measurements}}{\text{Expected Mesurements}}$$

4.4.61 KPI_SUC04_1: Performance of planning

4.4.61.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Measured in terms of improvement of the optimisation criteria.	**HLUC01, HLUC02, HLUC04, HLUC06**	**UdG**	**DE,ESP**

4.4.61.2 **Calculation**

Planning / scheduling operation require maximizing or minimizing a fitness function $\mathrm{F}(x)$, where x is the input vector defined by the variables to be adjusted. This KPI measures the improvement achieved by specific with respect the situation resulting of not applying any optimization.

Improvement of the Optimisation Criteria (IOC):

$$SUC04\_1 = IOC = \frac{\mathrm{F}(x)}{\mathrm{F}(x_{opt})}\ (x100) \qquad [\%]$$

With:

x: input vector that provides the optimal solution

x_{opt}: Input vector in case of not applying the optimal solution

4.4.62 KPI_SUC05_01: Asset state response time

4.4.62.1 **Overview**

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Asset monitoring response time is defined and respected (within agreed limits)	**HLUC04, HLUC05, HLUC06**	**INEA**	**DE,ESP, CY**

4.4.62.2 **Calculation**

The KPI is calculated as an average time from sending the schedule assignment and reception of the prosumer state change. The following state transitions are taken into account

- From 2 – available to 3 – waiting for execution
- From 2- available to 4 – in adaptation

The time is calculated as average:

$$SUC05\_1 = t_{avg\_state} = \frac{\sum \Delta t}{N}$$

where:

N: number of state changes

4.4.63 KPI_SUC05_02: Asset control reaction time

4.4.63.1 **Overview**

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots

Asset control reaction time is defined and kept (within agreed limits)	**HLUC04, HLUC05, HLUC06**	**INEA**	**DE,ESP,CY**

4.4.63.2 Calculation

The KPI is defined as an average time from the “startAt” parameter value in schedule assignment and monitored power change.

The time is calculated as average:

$$SUC05\_2 = t_{avg\_pwr} = \frac{\sum \Delta t}{N}$$

where:

Δt: difference between startAt and time at ΔP<>0.

N: number of adaptations

4.4.64 KPI_SUC06_1: Number of Flexoffers per time unit

4.4.64.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Expresses a total number of Flex-Offers generated within a time unit	**HLUC04, HLUC05, HLUC06 ,HLUC08, HLUC09, HLUC12, HLUC13, HLUC14**	**INEA**	**DE,ESP,UCY**

4.4.64.2 Calculation

The KPI is calculated as a ration between received number of flexoffers and observation period:

$$SUC06\_1 = t_{avg\_state} = \frac{N}{\Delta T}$$

where:

N: number of flexoffers,

ΔT: observationperiod (1 hour, 1 day)

4.4.65 KPI_SUC06_2: Flexoffer accuracy

4.4.65.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots

Accuracy of Flexoffers: MSE between predicted baseline energy and actual consumed energy	**HLUC09**	**INEA**	**DE,ESP,UCY**

4.4.65.2 Calculation

The KPI is calculated as normalized mean squared error of the two time series on the daily basis:

$$SUC06\_2 = \frac{\sum(E_{baseline} - E_{measured})^2}{\sum(E_{measured})^2}$$

where:

$E_{baseline}$: is calculated baseline.

$E_{measured}$: is measured energy from prosumer

4.4.66 KPI_SUC10_1: Performance of fault detection

4.4.66.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Ratio of false alarms and missed detections	**HLUC04, HLUC05,**	**UPC, EST**	**DE,ESP**

4.4.66.2 Calculation

See KPI_PUC01_2

4.4.67 KPI_HLUC03: Power continuity

4.4.67.1 Overview

Short Description	Relevant HLUCs	Responsible Party	Relevant Pilots
Reduction of individual average interruption duration / frequency index	**HLUC03, HLUC04**	**EST**	**DE,ESP**

The aim of this KPI is to evaluate the variation of the average duration and frequency of the service interruption within Estabanell's grid, considering the index used by Spanish regulators established in the *Real Decreto 1955/2000.*

For the calculation of this KPI, both quality and continuity have been considered. These two types of issues can be defined as above and are detected via the following channels:

- Quality issues: These can be due to voltage drop, harmonics or flickers, among others. Are only registered after a first contact call from the clients, through our call centre. A historical dataset from the last two years will be considered.
- Continuity issues: These can be due to what is considered an internal cause (programmed interruptions for maintenance purposes or unprogrammed interruptions due to grid failure) or due to external cause (force majeure or issues in the high voltage grid for example). Only

the first ones will be taken into consideration. These are registered by measuring devices placed on field, that send alarms to our grid control centre. A historical dataset from the last nine years will be considered.

4.4.67.2 **Calculation**

Based on the previously mentioned database, the average number of quality interruptions can be expressed as QI_{BAU} and calculated as follows:

$$QI_{BAU} = \sum_{i=1}^{k} n \ \ of\ registered\ complaints$$

Where *k* is the number of registered complains during the considered period of time. Unfortunately, for this kind of issues the duration of the problem is not registered, and therefore only the number but not the duration can be calculated.

When the FEVER technology is placed on the grid and tested, the registration of these type of issues will be also done. Therefore, the quality interruptions after FEVER technology deployment, can be expressed as QI_{FEVER} and calculated as follows:

$$QI_{FEVER} = \sum_{i=1}^{k} n \ \ of\ registered\ complaints$$

Where *k* is the number of registered complains during the considered period of time.

Based on the previously mentioned database as well, the average number (IN_{BAU}) and duration (ID) of continuity interruptions before FEVER project can be calculated as follows:

$$IN_{BAU} = \frac{\sum_{i=1}^{k} IP_i}{\sum IP}$$

Where:

IP_i is the installed power of the secondary substations plus the contracted power at MV (in kVA), IP is the installed power of the secondary substations plus the contracted power at MV (in kVA) affected by the interruption ‘i’ (in kVA)

k is the number of interruptions during the considered period of time before the FEVER project

$$ID_{BAU} = \frac{\sum_{i=1}^{k} (IP_i \cdot H_i)}{\sum IP}$$

Where:

IP_i is the installed power of the secondary substations plus the contracted power at MV (in kVA)

H_i is the supply interruption duration (in hours)

IP is the installed power of the secondary substations plus the contracted power at MV (in kVA) affected by the interruption ‘i’ (in kVA)

k is the number of interruptions during the considered period of time before the FEVER project

Following the same methodology and formulas, the same indexes can be calculated after FEVER technology is deployed, in order to do the comparison between the two. Therefore, the following calculations need to be done:

$$IN_{FEVER} = \frac{\sum_{i=1}^{k} IP_i}{\sum IP}$$

Where:

IP_i is the installed power of the secondary substations plus the contracted power at MV (in kVA), IP is the installed power of the secondary substations plus the contracted power at MV (in kVA) affected by the interruption 'i' (in kVA)

k is the number of interruptions during the considered period of time.

$$ID_{FEVER} = \frac{\sum_{i=1}^{k}(IP_i \cdot H_i)}{\sum IP}$$

Where:

IP_i is the installed power of the secondary substations plus the contracted power at MV (in kVA)

H_i is the supply interruption duration (in hours)

IP is the installed power of the secondary substations plus the contracted power at MV (in kVA) affected by the interruption 'i' (in kVA)

k is the number of interruptions during the considered period of time

With this, KPI_HLUC03 can be obtained as:

$$KPI_{HLUC03-qual} = \frac{QI_{BAU}}{QI_{FEVER}} \cdot 100\ [\%]$$

$$KPI_{HLUC03-Cont1} = \frac{IN_{BAU}}{IN_{FEVER}} \cdot 100\ [\%]$$

$$KPI_{HLUC03-Cont} = \frac{ID_{BAU}}{ID_{FEVER}} \cdot 100\ [\%]$$

5 Conclusions

This deliverable focuses on the description of the pilots, the validation methodology and metrics. It consists of the status quo, the progresses achieved, and the measures planned in the demo sites. Also, the document contains an overview of the sites and their respective infrastructure. Especially, the calculation and thus validation of the planned and needed progress set by the HLUCs at the pilots sites in Cyprus, Germany and Spain is displayed in detail. It describes which KPIs are relevant for quantifying the higher goals in form of the HLUCs and how they are calculated.

The Uses Cases described are essential to keep track of the processes and progresses within the project. The setting of higher goals which need to be quantifiable is necessary, as they help to grant good planning and communication between the different parties. This is the reason the different KPIs are displayed in such detail, as they make it possible to understand which factors and variables are important in each pilot to make sure that the aims of FEVER are continuously worked on, and progress is achieved.

In future, the updated planning in this deliverable give the basis for the technical installation as well as the putting into service of the pilots. When this is done, the data will be arising which can then be used to calculate the presented KPIs.

6 List of tables

7 List of figures

8 References

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List of abbreviations

Abbreviation	Term
AC	Alternating Current
AERP	Average of Efficiency of a reconfiguration plan
BAU	Business As Usual
BEMS	Building Energy Management System
BESS	Battery Energy Storage System
BUC	Business Use Case
CAPEX	Capital Expenditure
CNAE	National Classification of Economic Activities
COMGES	Component Manageable of the Expense
DAM	Day-Ahead Market
DAMSc	Day-Ahead Market Scheduler
DC	Direct Current
DER	Distributed Energy Resources
DG	Distribution Grid
DOA	Description of Action
DR	Demand Response
DSO	Distribution System Operator
EASE	Energy Used For Ancillary Services
EC	Energy Community
ECM	Effectiveness of Congestion management in Magnitude
ECT	Effectiveness of Congestion management in Time
EE	Exported Energy
EMS	Energy Management System
EST	Estabanell Distribucíon
EV	Electric Vehicle
EVM	Effectiveness of Voltage compensation action in Magnitude
EVT	Effectiveness of Voltage action in Time
EyPESA	Estabanell y Pahisa SA
FEMS	Factory Energy Management Systems
FLEX	Flexshape APS
FM	Flexibility Mechanism
FMO	Flexibility Market Operator
FMS	Flexibility Management System
FN	False Negative
FNR	False Negative Rate
FP	False Positive
FSCA	Flexibility Service Consuming Agent
FSPA	Flexibility Service Provider Agent
FTP	Flexibility Trading Platform
GOP	Grid Operation Planner

HIL	Hardware-In-The-Loop
HLUC	High Level Use Cases
ICOM	Intracom SA Telecom Solutions
INEA	Innovation and Networks Executive Agency
IOC	Improvement of the Optimisation Criteria
IPMA	Island Power Management Application
KPI	Key Performance Indicator
LEC	Local Energy Community
LETS	Local Exchange Trading System
LOC	Lost Opportunity Cost
LV	Low Voltage
MAPE	Mean Absolute Percentage Error
MED	Major Event Day
MER	Mercator
MgFMS	Microgrid Flexibility Management System
MgO	Microgrid Operator
MO	Market Operator
MP	Max Peak
O&M	Operation And Maintenance
OF	Objective Function
OPEX	Operational Expenditure
P2C	Power-to-Cold
P2P-FTP	Peer-to-peer Flexibility Trading Platform
PCC	Point of Common Coupling
PE	Produced Energy
PEDs	Power Electronic Devices
PFS	Power Flow Simulator
PQ	Power Quality
PQS	Power Quality System
PUC	Primary Use Case
PV	Photo Voltaic
PVTL	Photovoltaic Technology Laboratory
RES	Renewable Energy Sources
RMSE	Root Mean Square Error
RTBMM	Real-Time Balancing Market Mechanism
RTS	Real Time Simulator
RTU	Remote Terminal Unit
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control And Data Acquisition
SDS	Switchgear Dispatch Scheduler
SME	Small and Medium Enterprises

SOC	State of Charge
SOCP	Second-Order Cone Programming
SDS	Switchgear Dispatch Scheduler
SUC	Secondary Use Case
SWH	Stadtwerk Haßfurt GmbH
SWW	SWW Wunsidel GmbH
TEP	Total Energy Produced
THD	Total Harmonic Distortion
TMED	Med Threshold
TN	True Negative
TP	True Positive
TTE	Time required to extinguish the fault
TTI	Time required to identify the fault
TTM	Time required to propose a mitigation plan
UAS	Utilization For Ancillary Services
UC	Use Cases
UCY	University of Cyprus
UdG	Universitat de Girona
UP	Panepistimio Patron
UPC	Universitat Politécnica de Catalunya
V2G	Vehicle to Grid
VUF	Voltage Unbalance Factor