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D4.2

Outcome of DEMO 1 preparatory activities (HW and SW solutions implemented)

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D4.2	Work Package No.	WP4	Task/s No.	Task 4.2
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List of abbreviations

AMR	Automatic Meter Reader
AWS	Amazon Web Service
BSP	Balancing Service Provider
CBP	Crowd Balancing Platform
CCI	Controllore Centrale di Impianto
DEMO	Demonstrator
DER	Distributed Energy Resource
DERMS	Distribution Energy Resources Management System
DSO	Distribution System Operator
DMS	Data Management System
DSO TP	DSO Technical Platform
DTL	Dynamic Traffic Light
EMS	Energy Management System
FR	Flexibility Register
FSP	Flexibility Service Provider
GCP	Grid Connection Point
GFM	Global Flexibility Market
GIS	Geographic Information System
HW	Hardware
ISU	Industry Solution for Utilities
LDAP	Lightweight Directory Access Protocol
LFM	Local Flexibility Market
LV	Low Voltage
MDM	Meter Data Management System
MP	Market Platform
MQTT	Message Queuing Telemetry Transport
MSD	Mercato dei Servizi di Dispacciamento (Global Flexibility Market)
MV	Medium Voltage
NCS	Network Calculation System
NDA	Non Disclosure Agreement
NRA	National Regulatory Agency
PDC	Phasor Data Concentrator
PGUI	Power Grid User Interface
PMU	Phasor Measure Unit
POD	Point Of Delivery
SCADA	Supervisory Control and Data Acquisition

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SO	System Operator
STL	Static Traffic Light
SW	Software
TSO	Transmission System Operator
UVAM	Virtually Aggregated Mixed Unit

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1. Executive Summary

This deliverable is part of Work Package 4 – "South-Mid EU demo" and describes the activities carried out in Task 4.2 "*Demo preparation: SW and HW development for aggregator, DSO/TSO and market actors and engagement strategy*". The Task aim is the definition of the hardware (HW) and software (SW) components/subsystem requirements to address the effective and efficient implementation of the Italian Demo, enabling all the distribution resources to provide flexibility to the electrical system, as well as the customer engagement strategies for the Distributed Energy Resources (DERs) that will participate in Demo 1.

Starting from the plan and assessment methodology reported in T4.1, a description of the Demo overview activities is reported, illustrating the reference architectures useful for the TSO-DSO coordination scheme. After the procurement phase is treated, starting from the resource registration until the sharing of the local market outcomes. Moreover, the section about the activation and settlement describes the delivery and the evaluation of flexibility provided by the resources involved in the demo. To better perform the algorithm for voltage violations, in the Rome distribution network, Phasor Measure Units (PMUs) will be implemented in one or more secondary substations to enhance the grid observability. Finally, a cross-sector use case focused on the water distribution system describes the process to evaluate the flexibility potential of this asset.

All the platforms (Distributed Energy Resource Management System (DERMs), DSO Technical Platform, Crowd Balancing Platform (CBP), Flexibility Register (FR) and Market Platform) and the On field devices (Power Grid User Interfaces (PGUIs) and PMU) that will be installed in the demo's area, have been represented and analysed according to their architectures and technical requirements.

Finally, the document focuses on the Description of the grid, user characterization and customer engagement strategies that will be used in the execution of the Use Cases reported in the Demo overview.

The deliverable encloses two technical annexes that explain the complex interaction and information exchanged among TSO, DSOs and BSPs through CBP and FR for the flexibility procurement model, according to the coordinated scheme defined in the beginning of the document at a technical and business level.

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2. Introduction

With the increasing integration of renewable energy sources, the use of electric vehicles and the electrification of various sectors, the need for innovative flexibility procurement services and grid management strategies between DSO and TSO in the energy systems has become essential, challenging the energy market actors with innovative grid management strategies.

The BeFlexible project intends to promote prosumers' participation in the provision of flexibility by spreading knowledge about the advantages of their involvement and participation in the energy market. Regulation, Markets, Services Ecosystem, Platforms & Architecture, and Customer Engagement are the main pillars of the project. Each of them is important to achieve BeFlexible objectives, which include evaluating potential design options and assessing their viability, scalability, and replicability. Eleven pilots were deployed in four different EU countries to: 1) demonstrate flexibility potential; 2) evaluate consumer engagement strategies and foster market uptake; and 3) assess the impact of services, platforms, and architecture.

In this context, the key objective of work package 4 is to design and execute a demonstration campaign in which the coordinated qualification, acquisition/selection, activation, and validation of local and global flexibility services are tested. This is done by putting the identification of a reference architecture, the definition of services and Business and System Use Cases, and exploitation of solutions already established in prior EU/National projects RomeFlex, EDGE and the Pilot project on TSO-DSO Coordination (Traffic Light Mechanism).

Task 4.2 starts from the preparatory Demo framework and pilot validation plan described in Task 4.1 and Task 1.4/ Task 3.1 which finalise the Business and System Use Cases to define the activity and the reference architecture for the implementation of the Demo Campaign of the Italian Pilots 1.1 Rome, 1.2 Foggia & Benevento and 1.3 Cuneo reported in Table 1.

Table 1 - Business and System Use Cases Italian Pilots

Business Use Case (BUC)	System Use Case (SUC)	Pilots
BUC04. Long-term distribution grid congestion management	SUC04.1 – Long-term load forecasts SUC04.2 – Tools for quantifying flexibility needs in a constrained grid point SUC04.4 – Activate market-based and non-market-based long-term availability contracts	Pilot 1.2 Pilot 1.3
BUC06. Short-term congestion constraints forecasting and management for local flexibility service activation	SUC06.1 – Short-term Flexibility procurement based on congestion forecasting	Pilot 1.1

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	SUC06.2 – Short-term Flexibility activation for DSO congestion management	
	SUC06.3 – Settlement of flexibility services from DER participating to local market	Pilot 1.1
BUC07. Short-term voltage constraints forecasting and management for local flexibility service activation	SUC06.1 – Short-term Flexibility procurement based on congestion forecasting SUC06.2 – Short term Flexibility activation for DSO congestion management	Pilot 1.1
	SUC06.3 – Settlement of flexibility services from DER participating to local market	Pilot 1.1
	SUC07.4 – Online monitoring and observability enhancement to quantify the actual voltage condition	Pilot 1.1 Pilot 1.2 Pilot 1.3
BUC08. Crowd Balancing: Interoperable data exchange between stakeholders	SUC08.1 – Flexibility Register SUC08.2 – Market data exchange functionalities	Pilot 1.1 Pilot 1.2 Pilot 1.3
	SUC08.3 – Traffic light data exchange functionalities SUC08.4 – Verification functionalities	
BUC09. Local and global market coordination for distributed resources system service provision	SUC08.1 – Flexibility Register SUC08.2 – Market data exchange functionalities SUC08.3 – Traffic light data exchange functionalities SUC10.1 – Ex-ante validation SUC06.2 – Short term Flexibility activation for DSO congestion management SUC10.2 – Constraints definition SUC10.3 – Bids placements and verification SUC06.3 – Settlement of flexibility services from DER participating to local market	Pilot 1.1 Pilot 1.2 Pilot 1.3
BUC10. Dynamic constraints management for global flexibility activation in transmission system operation	SUC10.1 – Ex-ante validation SUC10.2 – Constraints definition	Pilot 1.1 Pilot 1.2 Pilot 1.3

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	SUC10.3 – Bids placements and verification	
BUC11. Capitalizing on flexibility available by leveraging on water distribution network assets	SUC11.1 – Evaluate the flexibility capability of water distribution networks	Pilot 1.1

Task 4.2 primary objective is to define the reference architecture, and technical/business requirements for the coordination between DSO and TSO about the qualification, acquisition/selection, activation, and validation of local and global flexibility services to be tested in a simulated environment. Furthermore, T4.2 will define all the hardware and software tools needed to perform the demonstration campaign, also testing advanced solutions for remote control and grid automation through Power Grid User Interfaces (PGUI), as well as explain the customer engagement strategies to involve the user from the Regulatory pilots (ex 352/2021/R/eel act) Edge and RomeFlex to test the Use Case for the activation and settlement of DERs.

The deliverable is composed of 4 chapters:
1) Demo overview that is composed of the Definition of the reference architecture for the step-by-step procurement of global and local flexibility services in a coordinated process between TSO and DSO, and the Description and implementation of the Business Use Case and System Use Case in which the Demo pilots are involved with detailed reference to BUCs:

- *BUC08 - Crowd Balancing, Interoperable data exchange between stakeholders*, *BUC09 - Local and global market coordination for distributed resources system service provision* and *BUC10 - Dynamic constraints management for global flexibility activation in transmission system operation* for what concerns the activity related to the simulated procurement of global and local flexibility services in a coordinated process between TSO and DSO.
- *BUC04 - Long-term distribution grid congestion management* and *BUC06 - Short-term congestion constraints forecasting and management for local flexibility service activation* for what concerns the activation of DERs in the pilots of Rome, Foggia & Benevento and Cuneo.
- *BUC07 - Short-term voltage constraints forecasting and management for local flexibility service activation* for what concerns the monitoring and grid observability through the PMUs developed by RWTH Aachen.
- *BUC11 - Capitalizing on flexibility available by leveraging on water distribution network assets* for the calculation of the potential flexibility on the water distribution network, to be made available for the electrical grid, to be tested in collaboration with four companies from the Acea Water Distribution Service.

2) Description, definition, requirements and technical specification of the platforms and software composing the reference systems architectures in the Demo Campaign.

3) Description, definition, requirements and technical specification of the on-field device and hardware, composing the reference systems architectures, that will be installed in the Demo Campaign.

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4) Description of the grid, user characterisation and customer engagement strategies to perform the activities described in *BUC04 - Long-term distribution grid congestion management* and *BUC06 - Short-term congestion constraints forecasting and management for local flexibility service activation*.

Furthermore, Deliverable 4.2 is completed with two annexes that list all the data business and technical requirements exchanged among the BSPs, the TSO and the DSOs.

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3. Demo Overview

3.1. Introduction

TSO-DSO coordination at market level is necessary since DSOs in Italy are starting to acquire congestion management and voltage control services (hereby called: flexibility services) offered by the same resources which now are mostly providing global services. Among the different market models, the *multi-level market model* given in CoordiNet[1] has been chosen given that pilot projects for DSO procurement of flexibility are already in place in Italy (EDGE[2], RomeFlex[3]) and considering that the scope of the South-Mid EU demo focuses on testing the coordinated selection and activation of flexibility resources. Indeed, this model considers two separate buyers of flexibility (TSO and DSO) and different market-based procurement processes.

The coordination mechanisms are defined considering the four different phases identified to complete the procurement process: 1) registration; 2) prequalification; 3) market and planning phase; 4) monitoring, activation and settlement. Considering that the procurement of local flexibility services for the Italian pilots are already implemented, the registration procedure of resources is coordinated keeping the current procedures of the different pilots. However, a further coordination step is introduced considering the possibility for Flexibility Service Providers (FSPs), that own already registered assets, to start offering services to the other system operator or, similarly, for those FSPs willing to provide both local and global services. The entire methodology is described in detail in Section 3.2. The main scope is to simplify and accelerate these phases for both system operators, who are entitled to verify whether some services can be enabled for a flexibility asset, and service providers, who can undergo a single registration and prequalification procedure. The market and planning phase concerns the short-term planning and selection of flexibility. The timing scheme is organized according to the actual structure of Mercato dei Servizi di Dispacciamento, MSD (see Figure 1): six different sessions (blue) each of which is specifically dedicated to four hours of delivery (dark grey). The local planning phase or Local Flexibility Market, (LFM) closes before the global market phase (MSD) when looking at the same delivery period. The definition of this planning schedule pushes forward a priority during the selection of share resources to the DSO when looking at the first session; DSO are entitled to select resources in advance with respect to TSO. This mechanism has been defined as the *principle of mutual unavailability* of shared assets: thus, those assets which have already been selected by a system operator in a planning session must be made unavailable for the following planning sessions. The definition of such mechanisms excludes the possibility for an asset to provide services at the same time for both TSO and DSO, thus it is not necessary to coordinate the monitoring, activation and settlement phase and they can be handled separately by the SO who procured it.

[1] https://coordinet.netlify.app/

[2] https://www.e-distribuzione.it/progetti-e-innovazioni/il-progetto-edge.html.

[3] https://www.areti.it/conoscere-areti/innovazione/progetto-romeflex

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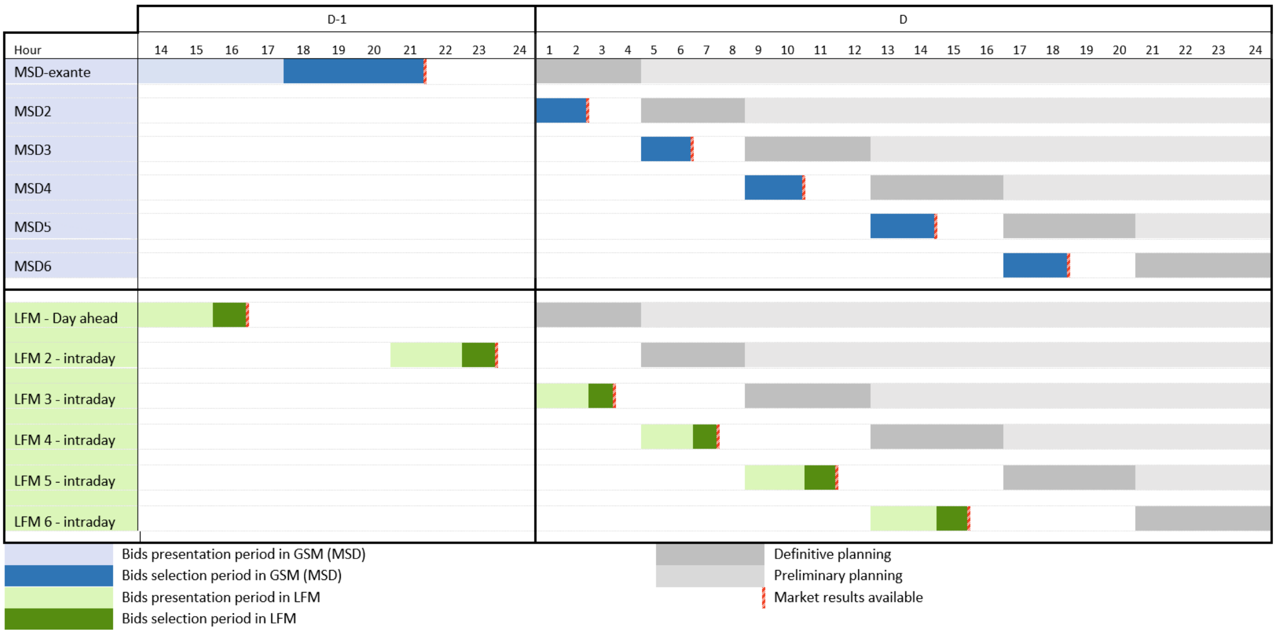

Figure 1 - Global (MSD) and local (LFM) planning sessions in sequence

Given the presence of a separate market platform, the coordination procedure is strictly based on information exchange. DSO informs TSO of their activation planning, TSO informs BSP of the selected offers in MSD and BSP reviews offers for the following session in the local market (LFM in green Figure 2).

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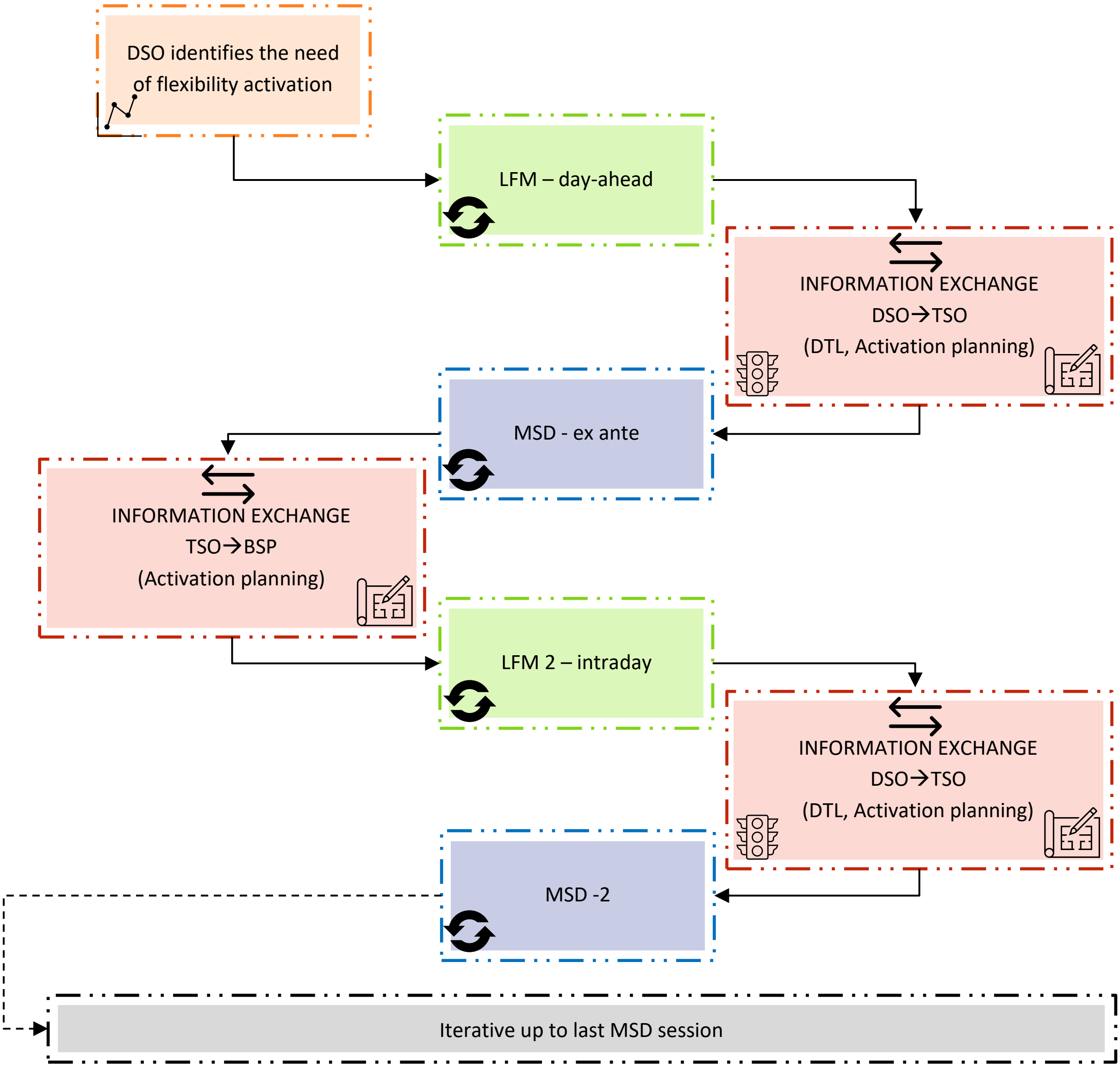

Figure 2 - Flow diagram of TSO-DSO coordination

The coordination mechanism described above (Figure 2**¡Error! No se encuentra el origen de la referencia.**) between TSO and DSO will be simulated, introducing simulated share flexibility assets, and simulating the overall process of information exchange to test the tools and platform developed and their functionalities.

3.2. Reference Architecture

Starting from the results achieved in Deliverable 4.1, a reference architecture has been defined to overarch the main steps expected in the flexibility market procurement. The scheme enables two entry points to address the resources in the local market or in the global market, implementing a standard data and protocol to seamless the information exchange. In the local Flexibility Market, the BSP fill in their data in the Flexibility Register (FR), a centre and unique database to gather the data of the Distributed Energy Resources (DERs) for DSOs. FR broadcasts the information to the DSO that triggers the actions in the Local Flexibility Market

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(LFM) sharing the outcomes with the FR. Moreover, In the Global Flexibility Market, the BSP registers the DERs on the Crowd Balancing Platform (CBP), leveraging on his data registry functionalities (as built in its Flexibility Register module), and its blockchain ledger, which stores the information and broadcasts them firstly to the TSO for accessing the "Mercato dei Servizi di Dispacciamento" (MSD) in Italy and then to the FR in order to acquire the Static Validation from the relevant DSO. For the DERs registration process, FR and CBP are interfaced and continuously updated to avoid misalignments that could impact the energy market.

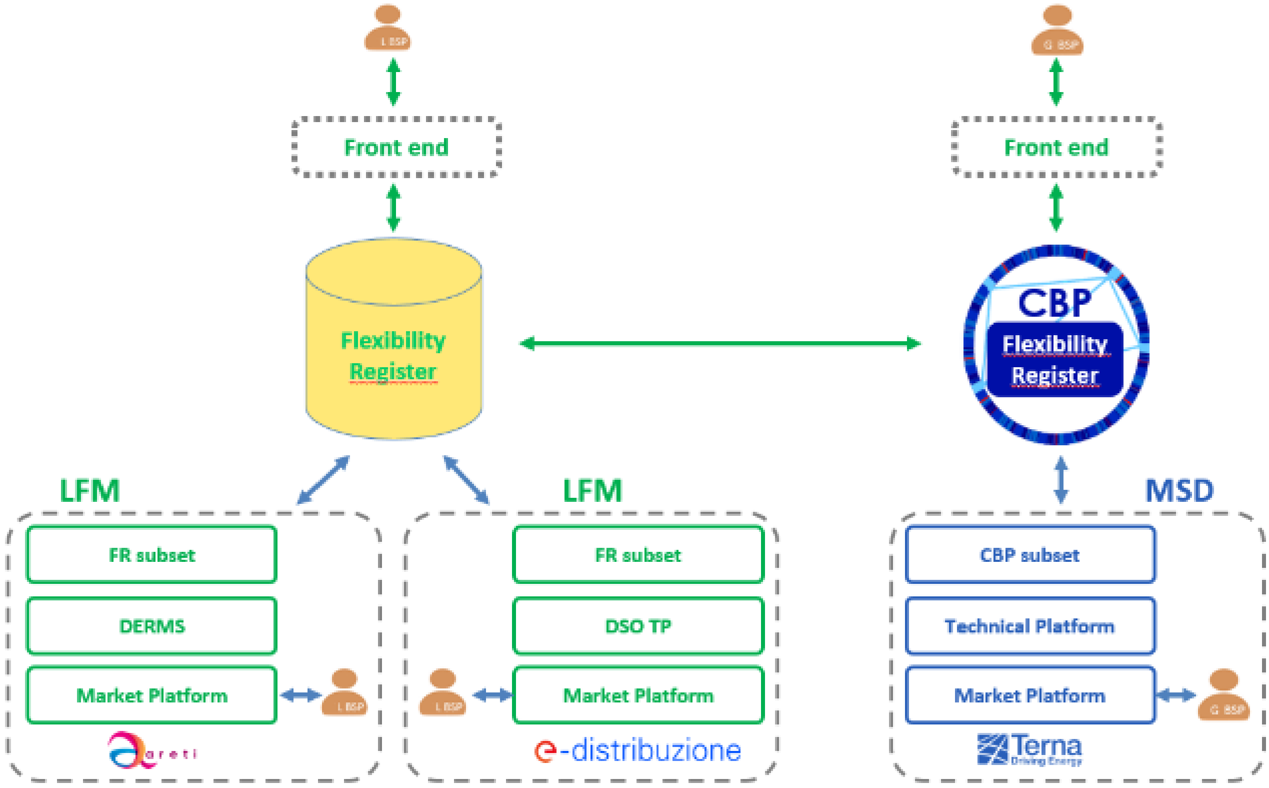

Figure 3 - Reference architecture TSO-DSO coordination

The architecture handles one global flexibility market (MSD) interfaced with CBP and several LFMs connected to FR, in this way the pilot defines a single archive for distribution operators to standardize the datasets and protocols, foreseeing the sharing of the information and overcoming the lock-in mechanism.
Coherently with the business use case and system use cases invoked in the WP4, this architecture supports the following phases:

- Resource Registration.
- Static Traffic Light 'STL' (or Resource validation).
- Aggregates registration (or Product qualification).
- Local market outcomes communication.
- Dynamic Traffic Light 'DTL' (or Dynamic validation).

The phases are described in detail in the following process paragraph.

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3.3. Process

In this paragraph, each step concerning the functioning of the reference architecture will be thoroughly described, considering both the actions and the information exchanged between the actors and the platforms involved in the processes. For what concerns the data exchange between BSPs, TSO and DSO please refer to annex 1 and 2 business and technical requirements.

3.3.1. Resource Registration

The first step performed is the resource registration and prequalification, thanks to the double entry point this can happen both via the Flexibility Register for the local market and via the CBP for the global market.

Following we describe the possible scenarios for the resource registration phase:

1. Resource registration and participation only in the local market: the BSP inserts on the FR the Distribution Energy Resources. The DSO, refer to LFM, receives the data and starts the check for the validation phase, at the end it shares the outcomes, in terms of resource information and its static validation, with the FR and broads it to CBP. This scenario must be considered a one-time event with the option of updating the resources information through the Flexibility Register (Figure 4).

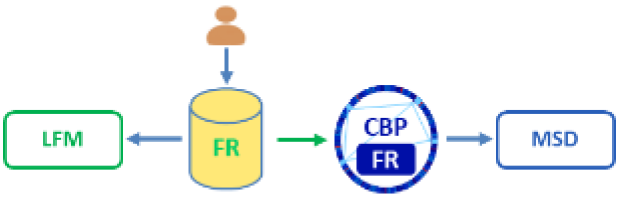

Figure 4 - Resource registration and participation only in the local market

2. Resource registration and participation only in the global market: the BSP inputs the data in the CBP invoking the "Register Flex Resource" service through the BSP node. The interaction with the FR will come after, during the validation phase. The DER registration has to be considered a one-time event with the option for the BSP to always update the information regarding the resource by using the Update Resource service (Figure 5).

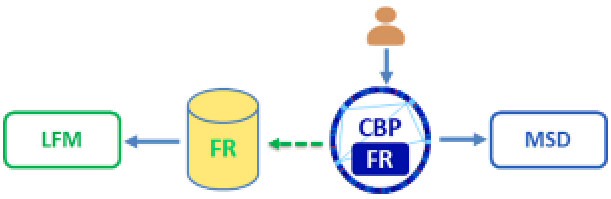

Figure 5 - Resource registration and participation only in the global market

3. First registration in the local market, next participation in the global market: starting from the registration of resources through the local market, the BSP fills the FR dataset. The FR triggers the

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check of the DER and transfers info to TSO via CBP. Then, to enroll the resource in MSD, the BSP registers the Point of Delivery (POD), on CBP using some of the previous information provided for the Local market (Figure 6).

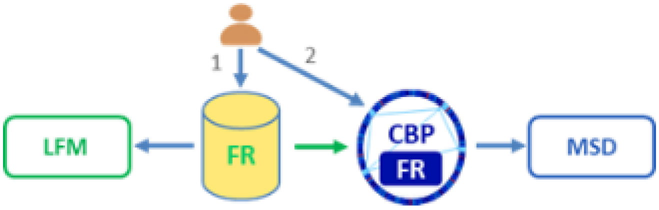

Figure 6 - Resource registration in the local market and participation in the global market

4. First registration in the global market, next participation in the local market: the BSP fills the CBP dataset to enroll the resource in the global market. The CBP calls the FR to trigger the "Static Traffic Light (STL)" process. When the BSP registers the resource also in the local market some information will be pre-filled through the info provided for the STL (Figure 7).

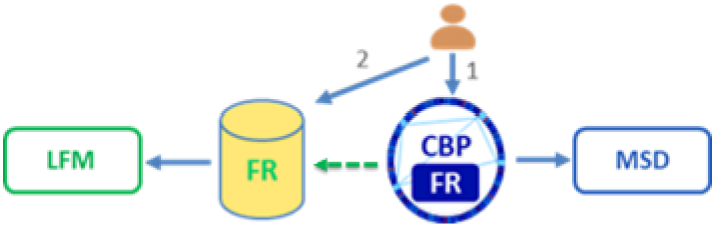

Figure 7 - Resource registration in the global market and participation in the local market

3.3.2. Asset validation or Static Traffic Light

All the resources directly connected to the distribution network and involved in the global flexibility market, need to DSO check, to certify the possibility that they can provide the ancillary services. The Static Traffic Light (STL) process ensures that the DERs, after the registration phase, can be enabled in the flexibility market. The STL is based on anagraphic and technical data inputs to perform the check.

The STL can be described in two steps:

1. Request to DSO: The TSO, through the CBP, after the resource registration phase for global markets, submits the request for static validation (STL - Grid Prequalification) to the FR which makes it available to the proper DSO (Figure 8).

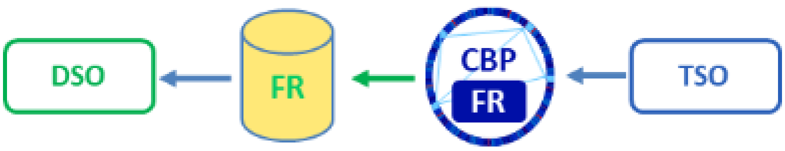

Figure 8 - Step 1 static traffic light request to DSO

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2. DSO check and results communication: the DSO performs the STL based on the data available from the registration phase on the FR. After he forwards the results to FR, which shares the information with CBP. The CBP communicates the outcomes to the TSO and the respective BSP (Figure 9).

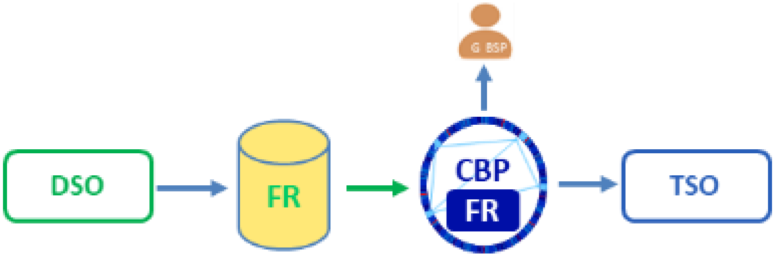

Figure 9 - Step 2 static traffic light DSO check

At the end of this phase, the resource is qualified and ready to be associated with a group of resources to take part in the global market.

3.3.3. Aggregates Registration – Product Prequalification

The product prequalification verifies that BSPs can provide the promised services employing the registered resources or aggregate of resources. In this step is checked if the technical requirements of a product or service are coherent.

At this stage, the BSPs, through the CBP or FR systems have to create an aggregate and link it to the number of DERs previously registered and validated. As for the resource registration phase, it's possible to observe different scenarios regarding the registration of aggregates through the local market or the global market and their participation in both markets:

1. Registration and participation in the local market: The BSP registers the aggregate on the FR which transfers info to the TSO via CBP. The resource pooling is connected with the distribution network perimeter defined by DSO. Due to the dynamic change configuration of the DSO grid, especially in an urban context, it may not be possible to define an aggregate so the BSP must consider a Grid Connection Point (GPC) as the point of aggregation (Figure 10).

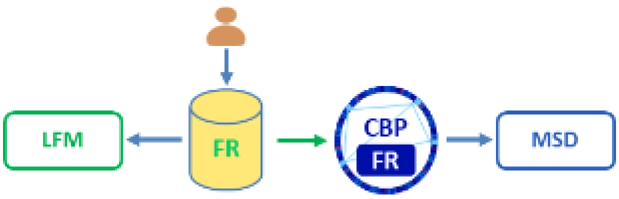

Figure 10 - Aggregates registration only in the local market

2. Registration and participation in the global market: The BSP registers the aggregate on the CBP that transfers the info to the TSO (Figure 11).

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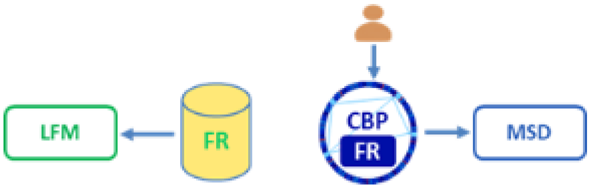

Figure 11 - Aggregates registration only in the global market

In case a BSP wants to qualify an aggregate for both LFM and GFM, since services in the two markets require different information to be communicated, the registration will follow distinctly process 1 or 2 depending on the BSP planning for its participation in the markets.

3.3.4. Local market outcomes communication

The LFM and MSD sessions are coordinated, indeed the local results anticipate the gate closure of the corresponding global market session, in this way the resources selected by DSO are excluded from MSD.

The local market outcomes are divided into two stages:

1. LFM outcomes: After the LFM session is performed, the DSO uploads the results of the local market on the FR. This information is then forwarded to CBP and TSO (Figure 12).

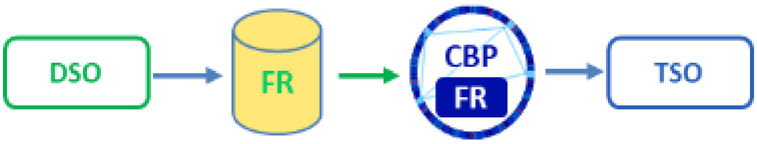

Figure 12 - Stage 1 local market outcomes

2. POD communications: in case of overlap of resources entitled to local and global services, the BSP may communicate with which resources it intends to provide the planned local service to make the remaining resources available for the global market. Otherwise, the whole unit (i.e. aggregate) must be considered employed in the previous market (**¡Error! No se encuentra el origen de la referencia.**).

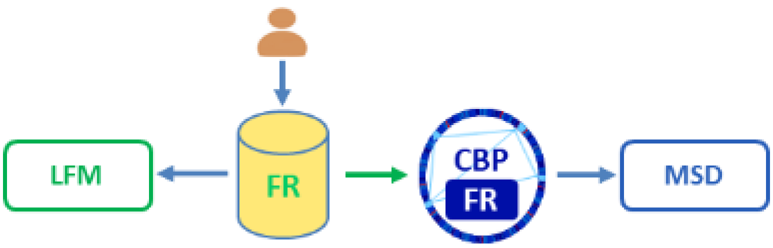

Figure 13 - Stage 2 local market outcomes

In case an aggregate is partially selected by the DSO to procure service for LFM, the BSP can communicate which resources will be used for service in LFM so that the remaining resources are not excluded a priori from GFM.

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3.3.5. Dynamic Traffic Light

In the planning phase of the GFM, coordination with DSO is crucial to avoid local grid violations when the DERs provide the global services. The DSO, for any market session, forecasts the state estimation and checks the compatibility of the DERs variation with grid limits, hence the DSO communicates the results to the stakeholders' TSO, this process is named "Dynamic Traffic Light" (DTL). Moreover, in this phase the DSO shares with the TSO the flexibility resources not available because connected to the grid under outage as explained in the introduction paragraph 3.1 of the Demo Overview.
In detail, the DSO uploads the DTL outcomes on FR, after the information is forwarded to the CBP, which transfers it to the TSO and the BSP (**¡Error! No se encuentra el origen de la referencia.**).

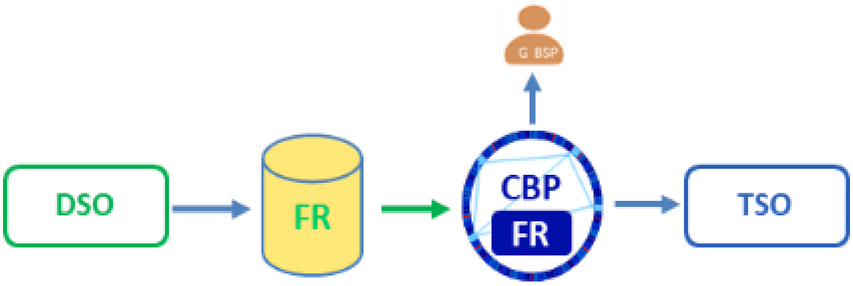

Figure 14 - Dynamic traffic light

The Dynamic Traffic Light (DTL) refers to a given DSO Perimeter for each hourly delivery period of the reference day in the form of a matrix consisting of these information vectors:

- Direction (up/down)
- Colour codification (red/yellow/green)
- Capability (MW)
- Motivation (if necessary)

However, as said before, the local resource pooling is connected with the distribution network characteristics. Due to dynamic change configuration of the DSO grid, especially in an urban context, it may not be possible to define an aggregate so the BSP must consider a GPC as point of aggregation.
The CBP receive the DTL from the FR through the Create Resource Constraint service on the TSO node, considering the following timeline:

- between 10:00 a.m. and 16:00 D-1, TSO receives in advance for each DSO the predefined DTL attributes (colour, capability, motivation, etc.). The outcomes are valid until a new updated coming from the DSO.
- by 16:00 D-1, the updated of the DTL attributes (colour, capability, motivation, etc.) replacing the default ones.
- To upload the DTL for the other market sessions of the day of delivery (D) the windows are:
    - By 23:00 D-1 with validity 04:00 - 23:00
    - By 03:00 D with validity 08:00 - 23:00
    - By 07:00 D with validity 12:00 - 23:00
    - By 11:00 D with validity 16:00 - 23:00

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- By 15:00 D with validity 20:00 - 23:00

The timing of the DTL communication is summarised below in Figure 15:

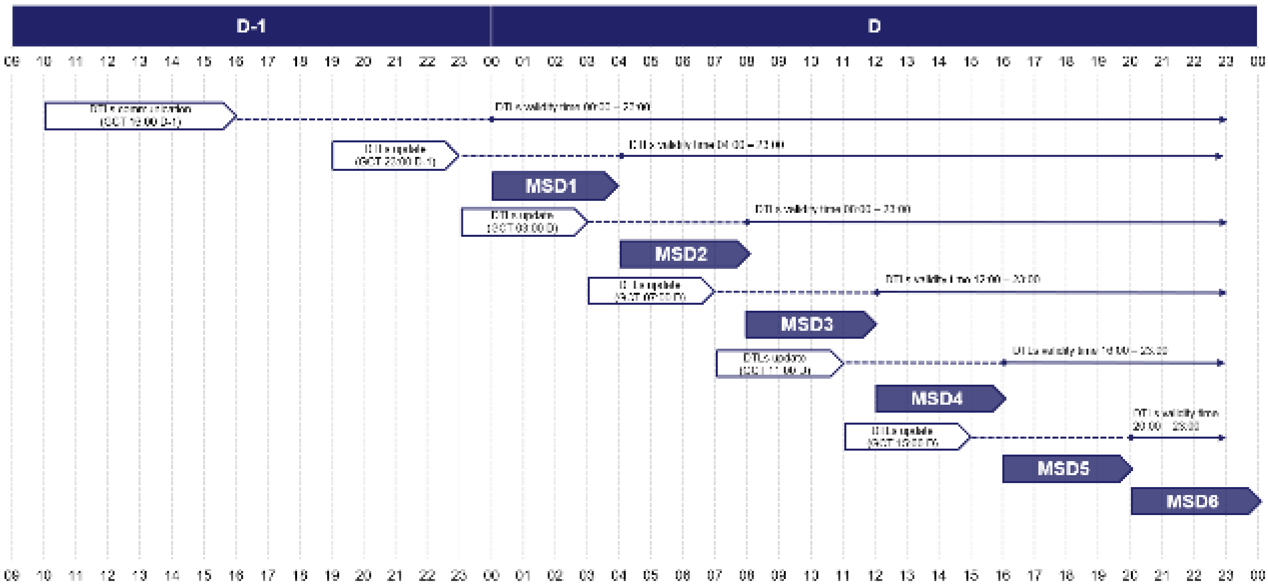

Figure 15 - Dynamic traffic light communication

In the case of DTLs communicated beyond the GFM closure, these are considered in the first subsequent session[4].

3.4. Grid Observability

Grid observability refers to the ability to continuously monitor and understand the status of an electrical power grid. This involves the real-time acquisition, processing, and analysis of data from various parts of the grid to ensure its efficient and reliable operation. Within the Italian Demo the *SUC07.4 "Online monitoring and observability enhancement to quantify the actual voltage condition*" will be implemented. The main objectives of the SUC are to Increase the LV nodes monitoring in real-time, to increase the MV nodes monitoring in real-time and finally use the real-time measurements to improve the grid simulation.

In the Pilot 1.1 Rome, to increase the grid observability, several nodes of the distribution grid will be equipped with devices able to gather, collect and send the data to the Distribution Management System (DMS). Moreover, exploiting the synergy with the experimentations ongoing, the resources involved in the flexibility market and the distributed power plants connected at the MV level, will be equipped with devices for real-time data collection at the Point of Delivery (PoD). An innovative measurement device, named Phasor Measurement Unit (PMU), will be tested to increase grid observability with a very high time resolution and accuracy. The PMU is an open-source low-cost device and relatively easy to integrate a measurement set, composed of actual and historical measurement data obtained from the dispersed metering devices (Automatic Meter Reader (AMR), Geographic Information System (GIS), Supervisory Control and Data

4 https://www.terna.it/it/sistema-elettrico/progetti-pilota-delibera-arera-300-2017-reel/progetto-pilota-coordinamento-tso-dso

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Acquisition (SCADA)) installed throughout the network, is available to the DSO for real-time operation purposes. The data refer to a) synchronised measurements of bus voltage phasors and line current phasors (magnitude and angle) and b) conventional measurements of power flows and voltage magnitudes at the top of distribution feeders, power injections from distributed generation units, and load pseudo-measurements for aggregated consumer demand at MV/LV transformer level[5].

Integrating a limited number of phasor measurement units (PMUs) into the grid infrastructure can significantly enhance its observability and improve the accuracy of state estimation algorithms. PMUs offer real-time synchronized measurements of voltage, current, and frequency at various points across the grid, providing crucial insights into its dynamic behaviour. By strategically placing PMUs at key locations, such as substations or critical nodes, operators gain a comprehensive view of grid dynamics, enabling faster detection and localization of disturbances or faults. When coupled with state estimation algorithms, which fuse PMU data with traditional SCADA information, operators achieve a more precise and real-time representation of the system's operating conditions. This fusion enhances the reliability and robustness of state estimation, particularly in scenarios involving complex network dynamics or contingencies. Moreover, the high-speed and synchronized nature of PMU data improves the temporal resolution of state estimation, enabling operators to capture transient phenomena and dynamic interactions with greater precision. Ultimately, this integrated approach empowers grid operators to make informed decisions swiftly, mitigating potential issues and improving overall grid reliability, stability, efficiency, and resilience.

The preliminary strategy to test the use case will consist first of deploying a PMU in a test environment and feeding it simulated voltages before installation in real substations, this procedure will offer several advantages. Firstly, it allows engineers and operators to validate the PMU's functionality, accuracy, and compatibility with existing systems under controlled conditions, ensuring its reliability and performance before deployment in critical infrastructure. Secondly, testing with simulated voltages enables the evaluation of various scenarios and fault conditions, helping to identify and address potential issues or limitations early in the development process. Additionally, it provides an opportunity to train personnel on PMU operation and data interpretation, enhancing their readiness to effectively utilize the technology in real-world scenarios. Overall, pre-deployment testing with simulated voltages helps minimize risks, optimize deployment strategies, and maximize the benefits of PMU integration into the grid infrastructure.

This will be achieved in two steps:

1. Device test and tuning (**¡Error! No se encuentra el origen de la referencia.**)

5 Guarnieri Calò Carducci, C.; Pau, M.; Cazal, C.; Ponci, F.; Monti, A. SMU Open-Source Platform for Synchronized Measurements. Sensors 2022, 22, 5074. https://doi.org/10.3390/s22145074

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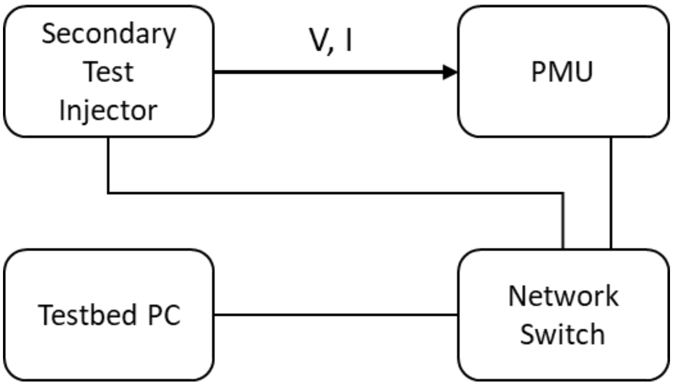

Figure 16 - PMU test and tuning

Where:

- The secondary test injector is used to send currents and voltages to the PMU.
- The PC will be equipped with all the programs to manage the system:
  - Secondary test injector interface (to manage the needed analogue values).
  - (The open Phasor Data Concentrator, PDC) PMU connection tester (to check locally if it is well commissioned and to read what is sending the PMU during my injection tests).
  - Anydesk (for remote connection).

2. Device integration and simulation tuning (Figure 17)

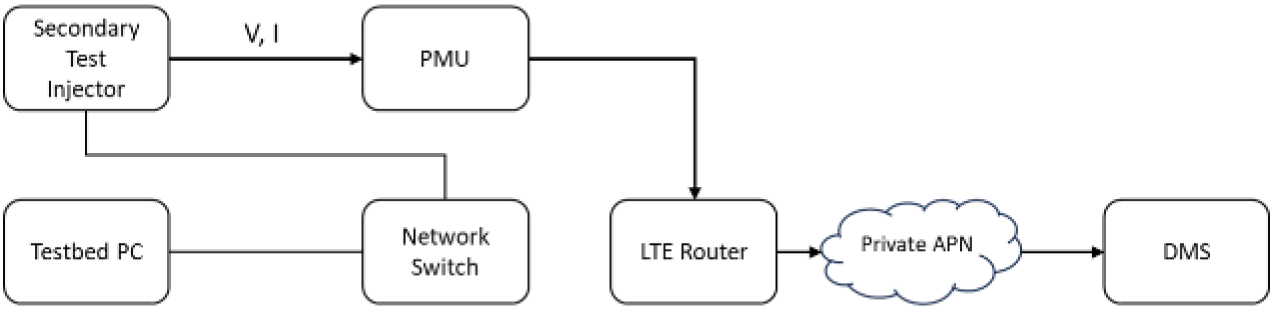

Figure 17 - PMU integration and test simulation

Where the scenario described in Step 1 is enriched with the possibility of uploading measurements to a Data Management System, DMS and replicating a real-world scenario.

In the pilot 1.2 Foggia & Benevento and 1.3 Cuneo the enhancement of the grid observability, in particular for the LV networks, will be tested through the implementation of the Chain3emulator. With this device's computational power and versatility, it is possible to establish a continuous dialogue with the smart meter via the Chain3 RF169 channel. The system manages the device's configuration and allows remote modifications, enabling the device to detect measurement logs at a currently configured frequency of 20 seconds. Additionally, the device can be configured to manage multiple smart meters in the future.

3.5. Activation and Settlement phase

One of the main objectives of the BeFlexible project is the active involvement of prosumers, this is also true for the national projects EDGE[2] and RomeFlex[3] which have the objective of developing a local flexibility market model under the overseeing of the Italian National Regulatory Agency, NRA. The WP4 Italian pilots act as an extension of the national projects, to further explore the coordination mechanisms and DERs activation, indeed the Italian pilots test the following SUC:

- **SUC 04.3 - Activate market-based and non-market-based long-term availability contracts:** This System Use Case (SUC) focuses on the execution of both market-based and non-market-based long-term availability contracts. This systematic approach is crucial for managing grid flexibility and maintaining stability in the power distribution network. The main objectives are to develop and implement a trading strategy, monitor the grid situation based on short-term load forecasts, activate suitable availability contracts according to the trading strategy and validate flexibility delivery using baseline and metering data from contracted service providers.
- **SUC06.2 –Short-term Flexibility activation for DSO congestion management:** In this SUC, the DSO activates flexibility products to manage grid congestions and voltage violations. These products, pre-reserved in a flexible market, supported by a Market Platform, are activated in real-time or close to real-time. It includes the flexibility activation of flexibility resources in the distribution grid, the verification of the reception of the activation signal (which should not be confused with the computation of the actual flexibility delivered), and the information exchange between all stakeholders in this process, enabling data as well as communication interoperability. With the objective of Monitoring conditions on the grid on real time, sending the activation signals and verifying information exchange between stakeholders and check the reception of the flexibility activation signal.
- **SUC06.3 – Settlement of flexibility services from DER participating to local market:** This SUC use available monitoring information to evaluate the response of the FSPs after the provision of flexibility service procured in a local market. The objective is to determine if the response of the FSPs corresponds to the awarded bids cleared by the short-term local market. This is done by gathering metering data and comparing it to a baseline. Financial settlement is calculated based on the delivered results, comparing the actual delivered flexibility and requested flexibility. In some cases, penalties may apply if described within the product specification. With the goal of quantify the delivered flexibility as response to activation request and calculate financial settlement based on the delivered results in comparison with requested quantity.

Coherently with the SUCs above described, two architectures defined for the pilot, about the activation and settlement phase are:

Activation phase (Figure 18): the resources selected in the procurement phase are activated to solve the grid issue. As an improvement of the EDGE and RomeFlex pilot schemes, the BSP can receive real-time information on flexibility assets and send them the ‘flexibility command’ (active power modulation) in two alternative manners: a) Using the DSO channel. In this case, the BSP sends the activation order to the DSO Technical Platform, which forwards it to Power Grid User Interface, (PGUI). The PGUI, hence, is connected to the Energy Management System (EMS). b) Using private communication with the EMS. The EMS performs the setpoints and provides the service.

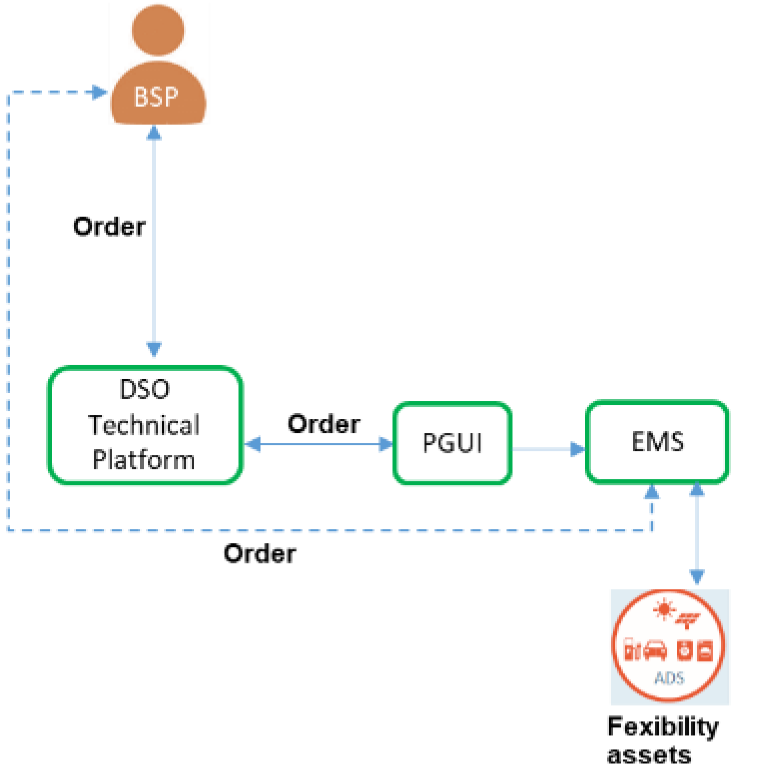

Figure 18 - DERs activation process

Settlement Phase (**¡Error! No se encuentra el origen de la referencia.**): The real time measurements gathered by the RomeFlex DERs' PGUI from the main meter are sent to the Flexibility Register. Moreover, the FR implements a baseline algorithm to evaluate the behaviour of the resources without flexibility activation. The Market Platform acquires from the FR the measurements and baseline, calculate the delivered flexibility and compare it with the requested flexibility, performing the settlements. At the end of this phase, the DSO receives the invoice and the BSP the payment for the energy moved.

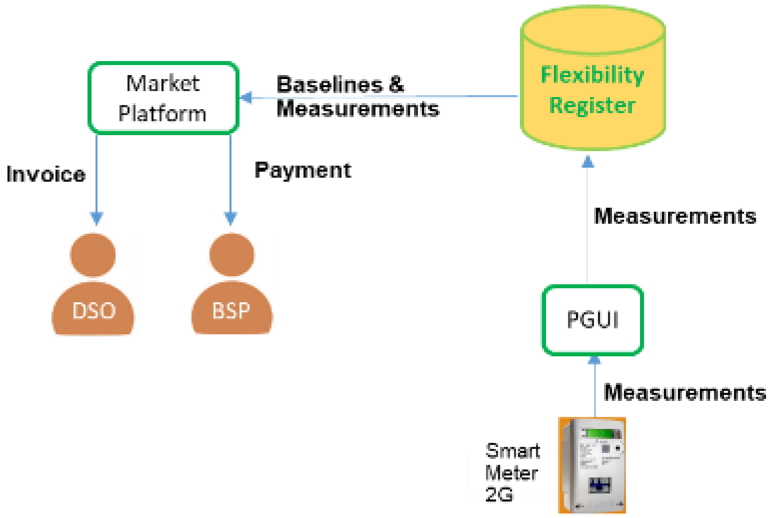

Figure 19 - DERs settlement process

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In the activation and settlement phase the PGUI plays a pivotal role, because:

- Enable the end user in the flexibility market.
- Gather the real time measurements from the smart meter.
- Certify on blockchain the measurements and flexibility order.
- Make available to the EMS the setpoint.
- Standardize the interface between grid and DERs.
- Overcome the lock in mechanism to enable the small flexibility assets.

3.6. Flexibility capability of water distribution networks

Use Case 11.1 “Capitalizing on flexibility available by leveraging on water distribution network assets” represents an innovative way of introducing flexibility energy provisions in the water distribution assets to avoid and solve electrical grid issues.

The large energy consumption of water facilities along with their flexible assets such as water pumps and tanks make them suitable candidates for energy efficiency and optimization applications. The main actors involved in the Use Case will be the WDS-O (Water Distribution System Operator) which is a party that is responsible for distributing and managing water resources from the withdrawal by supply sources to the final consumers and the EDS-O (Electric Distribution System Operator) who is a party that is responsible for distributing and managing energy from the generation sources to the final consumers.

This use case consists in quantifying the WDS-O flexibility potential to make it available to the electrical grid, this happens through three steps.

1. define the portion of the suitable asset/network for the use case. In this phase, the identification of the data set to be used in the simulations will also take place as well as the identification of the network topology. In detail, the data set will be composed by the nominal power of electromechanical equipment, energy consumption and active power of electromechanical equipment, flow rates, pressures, and energy performance indicators.
2. collect data in a defined time frame and analyse trend data and indicators to define a baseline for the asset.
3. simulate the hydraulic model in the new configuration with load shifting and evaluation of flexibility potential.

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4. Systems

The reference architecture, reported in the previous chapter, implements several components useful for the implementation of the demo. This section describes in detail the two technical platforms (DERMS and DSO Technical Platform) used by DSO to detect the flexibility needs in long- and short-term market, outlines the structure of the CBP and Flexibility Register as an entry point for the resource registration, finally treats the Flexibility Platform useful for the clearing and the settlement phases.

4.1. DERMS

4.1.1. Overview

The Enel DSO Technical Platform allows DSOs to improve reliability and quality of service by exploiting the flexibility made available from DERs connected to the grid. More in detail, the Platform, performing load flows within the distribution grid based on load forecast, is able to predict grid congestions and voltage violations, define flexibility needs to solve the forecasted criticalities, complying with market rules. To perform load flow and allocate flexibility, the Platform uses several grid data coming from DSO's Operational Systems. Once grid issue is forecasted, the Platform forwards automatically the flexibility allocation both to the BSP and to the market platform.

4.1.2. Architecture

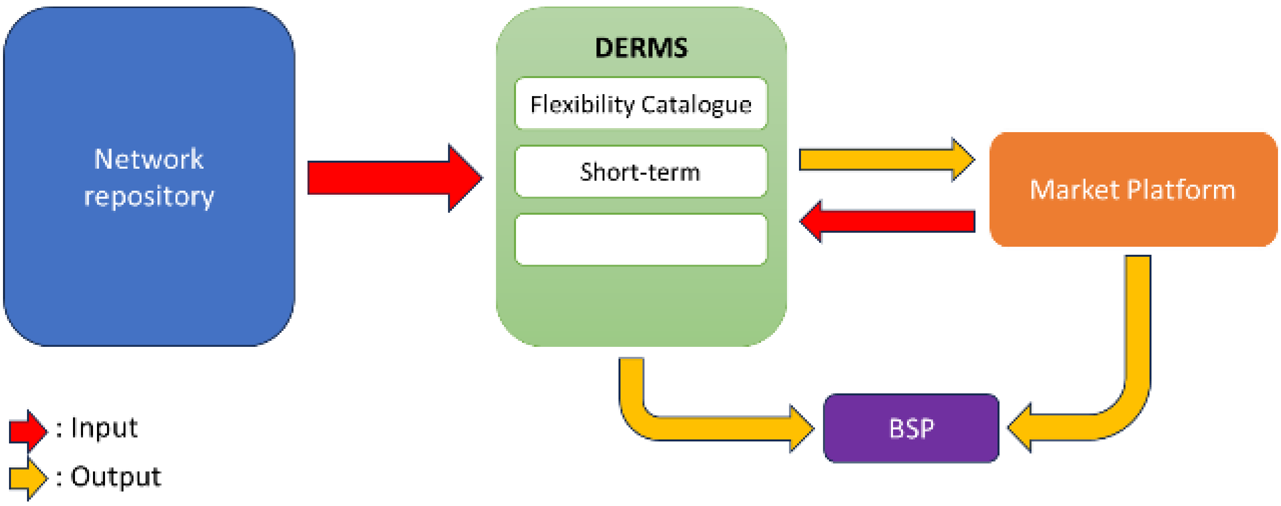

Figure 20 - DERMS reference architecture

The Distribution energy resource management system (DERMS) platform developed by Enel Grids receives data as input from a Network repository and gives as output flexibility needs to the Market Platform and activation request to the BSP through a messaging system (Figure 20).

Derms contains 2 main modules:

- Flexibility Catalogue

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- Short-Term

Flexibility Catalogue module

Flexibility catalogue is the module that:

- manages the catalogue of available flexibility contracts/resources & BSP registry.
- Manages the flexibility services workflow for activation.
- manages the integrations with external market platforms.
- Elaborates service dashboard & reports.
- coordinates with Enel Lightweight Directory Access Protocol (LDAP) users profiling & security.
- Manages alarms & messages to the operator & to BSP.
- manages of availability /unavailability of flexibility resources.

Short-Term module

The DERMS Short Term module identify daily criticalities (Current, Voltage, Power) of a particular portion of the grid over 2/5 days forecast period and compute the required (and desired) flexibility services (from existing available services previously contracted) to solve them in technical-economical optimal way, respecting the contracted market rules. The result of this computation can be approved by an operator in order to be activated.

4.1.3. Requirements and technical specifications

Enel Grids DERMS is the software that will help the control center operators to manage the grid of the future, where DERs are involved actively in solving grid congestions, supporting investments, and improving Quality of Service, benefiting the entire system, including the customers themselves.

DERMS is fully integrated with Enel' domains, which provide amongst others the following data:

1. Topological and nominal Grid data.
2. MV POD to connection nodes mapping and load profiles.
3. LV customers association and Load profiles.
4. Task & accounting microservices topology classifications.

Despite the automation of the procedure, operators still play a key role in the activation of flexibility service: the operators can approve, modify, or reject the flexibility allocation proposed by DERMS using network knowledge and experience to further optimize the process.

4.2. DSO Technical Platform

4.2.1. Overview

The Areti DSO Technical Platform (DSOTP) is an innovative platform connected with SCADA and GIS, able to provide the following services:

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- Performing Grid State estimation.
- Sending flexibility requests to the Market.
- Performing Dynamic Traffic Light Mechanism.

DSOTP receives the data coming from monitoring and control system, such as voltage and current measurements acquired by field devices and historical data from meters. Moreover, it acquires by the SCADA the circuit breakers state and real configuration of the grid. The tools implemented in DSOTP performs the grid forecast to detect the grid congestions, coherently with the timeline defined into the market sessions. A User Interface (UI) shows the violations highlighting the main characteristics (issue type; value; duration; direction, asset involved, flexibility potential) and suggests the flexibility need to solve the problem.
The DSO Technical Platform receives from the Global Market via FR the resources involved in MSD, so it runs the state estimation setting the resources at max flexibility that can deliver, in such way the distribution grid security is guaranteed. The results of the simulation are uploaded on FR and share with the stakeholder, coherently with the Dynamic Traffic Light mechanism defined in Deliverable 4.1[6].

4.2.2. Architecture

The DSOTP consists of a three-layer architecture:

- UI Layer includes a dashboard to allow a DSO operator the updating of the computation parameters, evaluating computed requirements and services available.
- Services Layer provides the business logic, including the Power Flow Analysis, the Flexibility Requests function, and the Flexibility Offer Assessment.
- Data Layer provides the management of the data.

The communication layer allows the integration of external components and internal communication among the different layers within DSO Technical Platform. It provides both synchronous communication interfaces (REST APIs) and asynchronous communication interfaces (Message Broker).
To forecast the grid state, the DSOTP acquires data from several Systems:

- SAP (Industry Solution for Utilities, ISU/Meter Data Management System, MDM): for users' data such as PoDs code, the connection power, the state of the connection, the type of user and Smart meters.
- Metering Information System: system dedicated to management of measurements coming from MV meters.
- Weather Forecast.

Furthermore, DSO Technical Platform receives the following data from GIS and SCADA:

- Network topology.
- Network configuration.
- Network electrical model.
- MV and LV field measurements (busbar voltage and current module) coming from the field.

The algorithms work with quart horary granularity coherently with the future market settlement.
Hence, the DSO TP is a complex system of several cooperating modules, bound to two different network management systems owning the real time snapshot of MV and LV network. This complexity, involving

[6] https://beflexible.eu/wp-content/uploads/2023/12/BeFlexible-D4.1-DEMO-1-Methodological-Report.pdf

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several dedicated service hosts, is hidden to other systems as DSOTP shows a set of API endpoints and an Message Queuing Telemetry Transport, MQTT broker for message-oriented protocols, especially dedicated to PGUI communication.

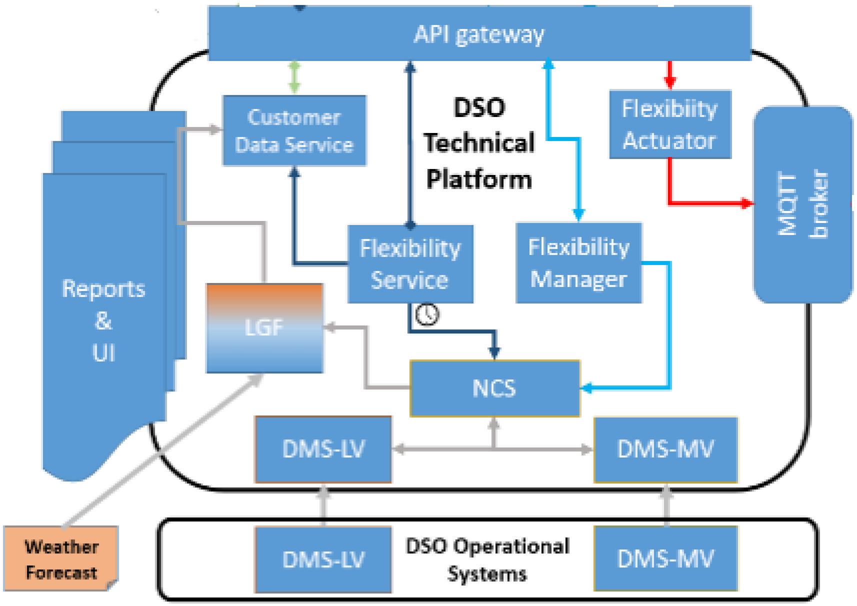

Figure 21 - Components and boundaries of DSO TP

The previous Figure 21 offers a picture of some DSOTP internal components (whose structure is out of the scope of this document) to provide evidence of the complexity of the system. It is also clear that DSOTP involves a direct communication channel with DSO Operational Systems (DMS-LV and DMS-MV) to be continuously synchronized with real-time network situations; in addition, the connection of DSOTP (i.e. "Load & Generation Forecast" tool) to Weather Forecast data is shown[7].

The NCS block (Network Calculation System) includes, both LV and MV networks, uses the following algorithms:

- Power Flow.
- Flexibility Requests function.
- Flexibility Assessment function.

4.2.3. Requirements and technical specifications

The DSO Technical Platform foresees the participation of many different actors, both persons and external systems.

Persons:

[7] Platone Deliverable D3.3 "Delivering of Technology v1" [Online] Available: https://www.platoneh2020.eu/Ressources/Deliverables

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- DSO TP Administrator, is the administrator of the DSO TP. He/she can: Insert computation parameters, evaluate computed requirements and evaluate required services.

External Systems:

- Market platform, is the system in charge of market clearing.
- Flexibility register, it is the system that provides information about the flexibility resources.
- The PGUI, is a device installed at DERs' premises that can receive the flexibility order from DSO TP and make it available to customer EMS.

The main functionalities implemented in the pilot by DSOTP are:

- Power Flows Analysis: This tool requires all the relevant electrical quantities (voltages, currents, active/reactive power flows, and losses) along the MV and LV distribution network, involved in the demo. Starting from the Power Flow results and based on configurable thresholds, the DSO Technical Platform detects the technical issues on the distribution network such as current overloads on branches (including lines, transformers etc.). The Power Flows are performed on: the LV network, starting from the LV busbar of each Secondary Substation transformer; MV network starting from the HV busbar of each Primary Substation. All the MV/LV Secondary Substation transformers that do not include any flexibility customers involved in the Demo are modelled considering an aggregated approach. Part of the results provided by the LV Power Flows (active and reactive power flows on the LV side of the MV/LV transformer) are used as an input for the MV Power Flows run at the upper hierarchical level. The DSO Technical Platform receives from SCADA systems the topology of the network, all the electrical data and the necessary dynamic data to set up the reference network configuration that is used for the different time slots.
- Flexibility Requests: this algorithm is triggered if some technical violations (voltage and/or current) are detected on the distribution network while running the set of Power Flows on the reference time window. Starting from the network scenarios, the "flexibility request" algorithm applies a specific optimization approach able to find, among the MV and LV customers that are actively involved in the project (i.e. available to provide flexibility services), those that can more effectively solve the DSO technical issues. The final result of the algorithm is a set of aggregated MV and LV customers (identified with different PoD lists) including, for each timeslot, the requested power profile; this data is the content of the "flexibility requests" that the DSO will send to the Market.

Validation of Flexibility Offers (Dynamic Traffic Light): The DSO TP implements a "flexibility assessment" algorithm that is triggered during market sessions. The preliminary step for this function is to run a set of Power Flows (on the reference time window) applying the selected flexibility services received from the Market for the resources involved in the Demo. Starting from the described basic network scenarios, the "flexibility assessment" algorithm applies a specific optimization approach able to exclude properly some of the flexibility offers with the final goal of fixing potential critical situations on network constraints and restoring safety operation on the DSO network. Performing the technical assessment, the algorithm considers the offers' "priority" order provided by the Market Platform.

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4.3. Crowd Balancing Platform

4.3.1. Overview

The Crowd Balancing Platform, CBP, is the platform developed by Equigy, a joint venture of Terna and other European TSOs, which aims to facilitate market access for new flexibility resources. In the scope of the BeFlexible project, CBP will assume the role of orchestrator between the various actors involved in the coordination of local and global flexibility markets.

Any interaction with the platform is performed via the Internet via API services as well as Cloud SaaS services.

The CBP platform is distributed in the cloud and operationally managed by Equigy. Each participating in the project is not required to install/configure any infrastructure components on its own systems.

4.3.2. Architecture

The Crowd Balancing Platform is built and operated as a distributed platform based on Hyperledger Fabric as Blockchain framework. The platform consists of two main components (Figure 22):

1. CBP Core - The heart of the Blockchain platform. Implements the "Core Platform" based on ENTSO-E and EBIX Standards and all functionalities related to security, monitoring, management, fraud detection and external audit functionality. It contains the platform's Smart Contracts with logic and transactions on Blockchain assets. Smart Contracts are distributed on the Blockchain because they also contain and maintain the World State database and the Blockchain Ledger.
2. CBP Apps - CBP Apps enable the platform to localise to each market deployment and operate within the specific laws, country regulations and specific use cases required. They contain the functionality for a specific market implementation, including the logic to connect to the APIs of the market players' systems with which it will need to integrate. CBP Apps implement the business logic for specific market processes and have a layer for integration with the Blockchain ledger.

The CBP platform can be managed in a distributed manner, where each participant can distribute one instance of the Blockchain (peer).

The platform supports multi-tenancy, which means that a single instance of a Blockchain peer and CBP App can be used by several participants while maintaining privacy and security requirements through the appropriate channels.
The solution defined for the Italian context for the integration of the CBP platform with Terna, BSPs and DSOs is depicted in the following image:

- Multi-Tenant Peer for FSPs.
- Multi-Tenant Peer for DSOs.
- Single-Tenant Peer for the TSO.

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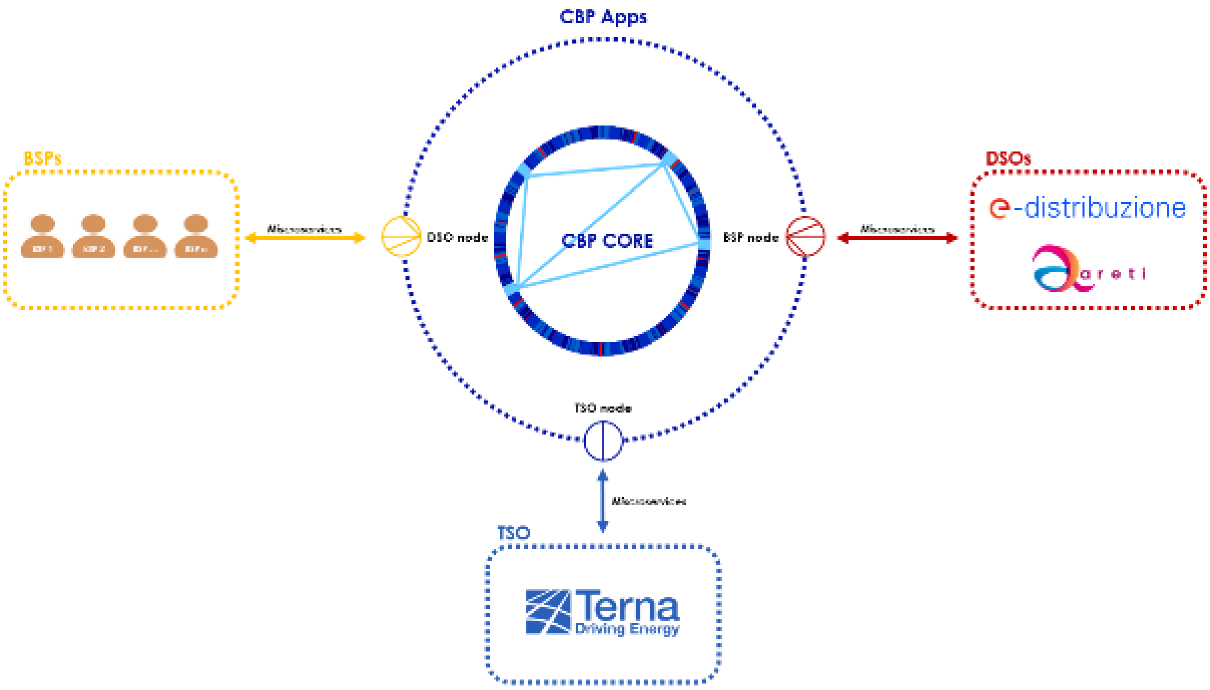

Figure 22 - CBP high level architecture

Through the definition of dedicated private channels for communication between each actor within the defined deployment model, the segregation of information necessary to guarantee data privacy within the Multi-Tenant Peer is defined.

4.3.3. Requirements and technical specifications

As already mentioned in the previous paragraphs, the CBP platform, leveraging on his data registry functionalities (as built in its Flexibility Register module), allows all stakeholders, such as TSO, DSOs and BSPs, to insert and update data related to business & non-business transactions in a certified blockchain ledger, that allows data to be stored and historicised in a secure yet easily accessible manner.

The platform connects with the users of its nodes through appropriate API interfaces, leaving the operation of their business to the users' own systems by providing functionalities for different areas of operation, that can be used on multiple market products and in different implementation contexts, like:

- Asset and pool registration.
- Prequalification.
- TSO-DSO coordination.
- Flex Offers management.
- Flexibility activation.
- Aggregate or distributed measurements and baseline calculation.
- Flex Delivery and configuration.

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- Validation and Settlement.

To these functionalities must be added those of monitoring and reporting through dedicated dashboards.

In the scope of the BeFlexible project, CBP will leverage functionalities linked to asset and pool registration, TSO-DSO Coordination:

- Asset registration for Flexibility Market.
- Asset Validation.
- Product prequalification.
- Local Market result communication.
- Dynamic Validation.

4.4. Flexibility Register

4.4.1. Overview

The Flexibility Registry (FR) is a repository system where all data relating to the flexible PoD is archived and made available to all stakeholders.

FR stores both general data on the resources such as the connection voltage level, power, etc.; and data characteristic of flexibility such as the available flexibility of resources, the type of market in which they operate, market outcomes, etc.

The data is organized in a programmed manner and can be read by authorized platforms and interested parties followed by authentication procedures.

4.4.2. Architecture

The flexibility registry consists of a multi-tiered architecture (Figure 23).
The architecture of the FR is as follows:

- From a front-end interface, (with related back-end) where information on flexible resources is recorded by authorized parties. The component that allows data recording and movement is represented by the Presentation Layer of the architecture. Furthermore, the Presentation layer is connected to the communication layer with which it transfers data to the CBP platform.
- From the Communication Layer capable of establishing bi-directional communication with the CBP. Specifically, the data compiled by the front-end masks (presentation layer) transit to the CBP, and vice versa from the CBP to the Flexibility Register (presentation layer).
- The Persistence Layer: represents the database and is made up of two databases:
    - Non-relational DB (MongoDB), populated by the communication layer, dedicated to the acquisition and historicization of data coming from the CBP and data coming from the interface (presentation layer).

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- Relational DB (Aurora Postgres) that is populated by Amazon Web Service (AWS). The data extracted and inserted are those present in the non-relational DB which need to be displayed and moved via the interface. It actually represents the database used by the front-end interface (presentation layer).

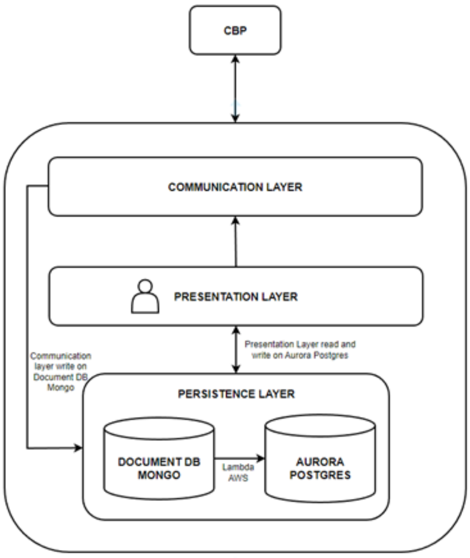

Figure 23 - Flexibility register architecture

The Layers constituting the architecture are strongly interconnected to each other to allow fast and immediate operation by users who use the platform.

4.4.3. Requirements and technical specifications

The subjects with whom the FR interacts are:

- The BSPs, from which it acquires the personal information of the distributed resources whether they participate in the Local market or the Global Flexibility market.
- DSOs that validate resources and define their Flexibility limits for the different types of markets in which the resources participate.
- The TSOs, to which all the registration and validation data of the distributed resources are sent, as well as the information relating to the market and aggregation outcomes of the resources. The information cited reaches the TSO through the use of the CBP platform.

The external systems with which the FR interacts are:

- The CBP with which it bidirectionally exchanges information relating to the registration data of the resource.
- The resource aggregation data, as well as the static and dynamic validation data of the resources themselves, are also shared with the same platform.
- The Blockchain Access Layer, the FR receives all certified measurement data, recorded by field devices (PGUI) (Figure 28).

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Main functionalities:

In the Italian Demo, the Flexibility Register has several tasks, and we have identified the following use cases:

- Census of Resources to Provide Flexibility Services.
- Indications regarding the Static Traffic Light.
- Communication of Local Market Outcomes.
- Communication of Dynamic Traffic Light.
- Generation functionality of the aggregate participating in the Local Flexibility Market, as well as the association of the PoDs to the aggregate itself formed by the BSPs.
- Bidirectional synchronization of data moved with the CBP platform.

Census of Resources to Provide Flexibility Services:

1. The FR acquires data from resources who wish to participate in flexibility.
2. The resource registration data are acquired directly by the FR if the resource is intended to participate in the Local Flexibility Market.
3. Or, the same data is acquired by CBP if the resource participates in the Global Flexibility Market.
4. Data loading operations are performed by the BSP.

An high-level case that depicts the relational flows notified between the different stakeholders aimed at detecting the availability of PoD between flexibility services is reported in Figure 4 and Figure 5.

Indications regarding the Static Traffic Light:

It is a functionality through which the DSO expresses the amount of flexible power for each resource presented by the BSP in order to qualify it for LFM or GFM, as reported in Figure 9.

For LFM participation the DSO fill the information for the STL on FR and then is shared with CBP. Subsequently, the CBP forwards the information to the TSO.

When the resource is registered by the BSP for the GFM, the TSO will share the resource information through the CBP, this way requesting the static validation.

Definition of aggregate and association of resources

For all validated resources that are permitted to participate in the flexibility market, the FR allows BSPs to

- Form aggregates.
- Associate PODs with each aggregate.

If the BSP performs aggregation tasks on FRs, they will be sent to CBP.

Communication of local market outcomes

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The DSO is assigned the task of reporting the results of the Local Flexibility Market in the FR, respecting the indications in the methodological report reported in figure 1. FR will then communicate the information for LFM results to the CBP which will forward it to the TSO.

Communication of Dynamic Traffic Light

It is a functionality through which the DSO expresses grid constraints to be used by the TSO during GFM execution. The DSO communicate the Dynamic Traffic Light (DTL), expressed for a given DSO Perimeter and for each hourly delivery period of the reference day, to the FR. The information regarding DTL are then shared with CBP which will forward them to the TSO.

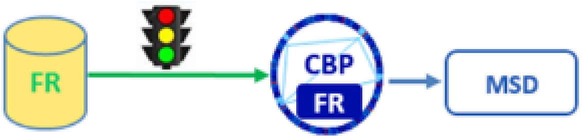

Figure 24 - Communication of dynamic traffic light

Bidirectional synchronization of data moved with the CBP platform

Making data available and processing them for operators is possible thanks to the high synchronization that the FR has with the CBP, regarding resources information for registration and static validation processes. The passage of information is guaranteed by securitised and efficient communication methods.

Figure 25 - Resource database alignment

4.5. Market Platform

4.5.1. Overview

The Flexibility Market Platform (FMP) extends and adapts the Platone Market Platform[8] , in order to be adopted and used in the Rome Demonstration of the BeFlexbile project. In this context, the main goal of the FMP will be to match the local flexibility requests of DSO with offers coming from BSP, following predefined rules and priorities. All transactions occurring within FMP can be securely recorded and validated through a blockchain service layer, ensuring transparency and reliability for all stakeholders participating in the market operations. In addition, the FMP will be also able to collect data from FR and perform the settlement process.

4.5.2. Architecture

The FMP consists of a three-layer architecture, Figure 26:

- Data Layer provides the management of the market data and the registration of the market operations within blockchain infrastructure.
- Services Layer provides the business logic, including the market-clearing tool, the flexibility services and the settlement services.
- UI Layer includes a web dashboard that allows market players to view their own market operations and Market Administrator to handle all the Flexibility Market Platform features.

In addition, the communication layer allows the integration of external components and internal communication among the different layers within the Market Platform. It provides both synchronous communication interfaces (REST APIs) and asynchronous communication interfaces (Message Broker).

[8] Platone Deliverable D2.3 "Platone market platform v1"" [Online] Available: https://www.platoneh2020.eu/Ressources/Deliverables

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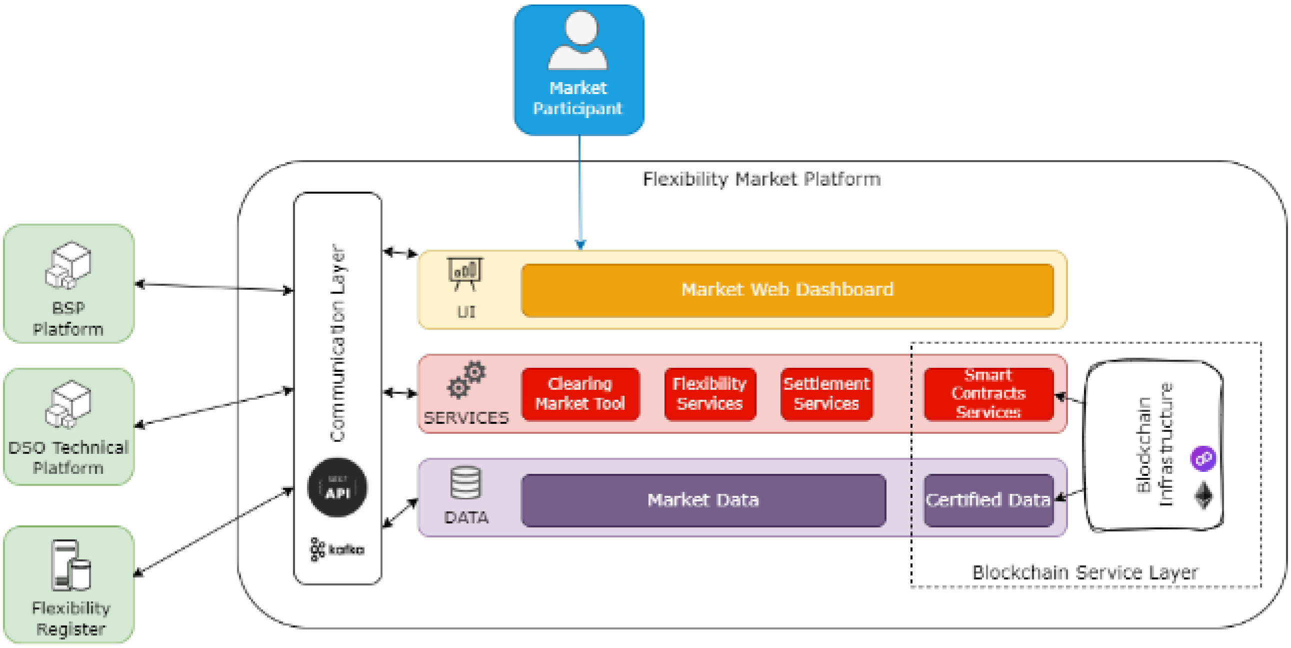

Figure 26 - Market platform architectural layers description

Data Layer: The Data Layer manages all the necessary data for the implementation of the Flexibility Market Platform services and it includes MongoDB for the storage of the data. Furthermore, this layer implements the business logic for the certification of the market data on the blockchain service layer.

Service Layer: The Service Layer is the core of the Market Platform and it includes all the services that implement the functionalities offered by the Market Platform. It is based on Node.js and Express.js architectural stack. The services implemented in this layer are Flexibility Services; Clearing Market Tool; Settlement Services.

UI Layer: The UI Layer includes the User Interfaces available for all the market participants. It includes a Web Dashboard, based on an advanced web JavaScript framework accessible by stakeholders for monitoring their activities (flexibility request and offers, market results, settlement results, etc.).

Communication Layer: The Market Platform architecture includes a Communication Layer, a specific component that provides two different communication mechanisms: synchronous and asynchronous. A specific architectural component dedicated to communication mechanisms provides greater flexibility to the Flexibility Market Platform, which can cover different solutions and integrate different external systems. In particular, the communication layer offers an interface for the integration of the any other existing platform. More in detail, the synchronous communication is implemented in the API Gateway via REST APIs. The API gateway is the entry point for every HTTP request that is being launched by the external systems. The API gateway is developed using the open-source framework Express.js and Express Gateway. This central component, shared by the whole Market Platform, allows the centralisation of some middleware

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functionalities. The asynchronous communication is implemented in the Message Broker. The Message Broker is implemented using Apache Kafka[9], an open-source distributed event streaming platform.

4.5.3. Requirements and technical specifications

The Flexibility Market Platform foresees the participation of different actors, both persons and external systems, following a brief description of the actors involved:

Persons:

- Market Administrator, he is the administrator of the Market Platform, he has access to the web dashboard, and he can manage all the functionalities of the Market Platform.
- Market operators: DSO and BSP can access to the dashboard to check and see the market results.

External Systems:

- DSO TP, is the system in charge of the creation of the local flexibility requests.
- BSP Platform, is the system in charge of the creation of the flexibility offers.
- Flexibility Register, is the system that provides information about the resources and the data for settlement phase.

Use Cases:

The Market Platform implements two high-level Functionalities:

Flexibility Services Management: The Market Place is a "virtual" place where the flexibility requests and offers match. Before starting the procurement phase, FMP receives or updates, through the FR, the list of flexibility resources available. Moreover, in each market session, FMP receives flexibility services requests from DSO and flexibility services offers from BSP. At the end of the market session, the FMP performs the market clearing based on economic criteria. First step is to find, among the various offers of the aggregators, those that meet the DSO request. All the offers that accomplish the request are ordered according to a price-based mechanism. At the end of the process, the market outcomes are shared with all stakeholders.

Settlement: After the activation phase, FMP is able to acquire the measurement and baseline data from FR, and to perform the Settlement process. Finally, the results are communicated to the stakeholders. At the end of the settlement phase, DSO receives all the necessary information that allows him to pay for the received flexibility service.

[9] https://kafka.apache.org/

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5. On Field Device

The implementation of the use cases in the pilots, requests the use of innovative devices installed on filed. Leveraging on the previous experience grown up in other European projects or in a Technical Committee Group (as Comitato Termotecnico Italiano (CEI[10])), to gather the real time measurements and transmit the setpoints to resources, the Italian demo adopts two kinds of Power Grid User Interface (PGUI) in Rome and in the other landscape. Moreover, to increase the grid observability of the Rome network, the Phasor Measure Unit (PMU) developed by RWTH will be installed in one or more secondary substations to increase the perform of the simulation tool able to detect the local voltage violations. In this section the report describes more in detail the following devices that will be tested in demo.

5.1. PGUI areti

5.1.1. Overview

The PGUI is an edge device installed on the customer's premises, enabling the collection of real time measurement data from smart meters deployed within Distributed Energy Resources (DERs). It receives flexibility activation commands and relays them to the customer's Energy Management System (EMS), facilitating integration with systems such as Storage Systems and Smart Home Devices. Subsequent sections outline the architecture of the PGUI apparatus and its associated communication protocols.

The PGUI facilitates the acquisition and certification of data from smart meters (including power, energy, voltage, etc.), providing this information to Flexibility Register. Additionally, it receives orders from third-party operators (such as DSOs) and forwards them to the Energy Management Systems (EMS), Figure 27.

[10] https://www.ceinorme.it/

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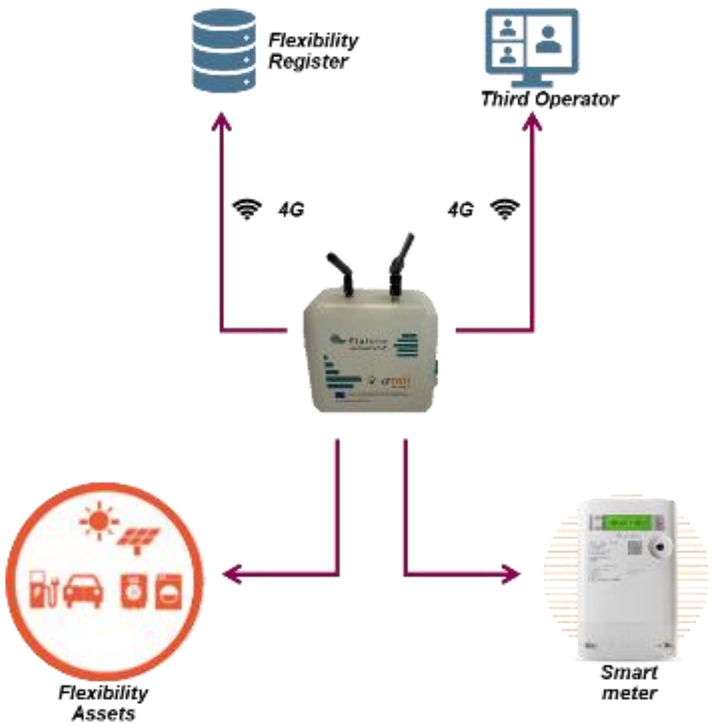

Figure 27 - PGUI communication system overview

Key functionalities of the device include:

- Real-time acquisition of data from the new generation of Smart Meter (referred to as Smart Meter 2G) via Power Line Communication protocol.
- Real-time acquisition of data through serial protocol from MV meters.
- Blockchain certification.
- Acquisition of set-points sent by third operator.
- Data exchange with EMS systems on customer premises.

5.1.2. Architecture

The PGUI consists of two layers and two interfaces, Figure 28:

- Data Layer, which provides connectivity to the Blockchain Access Layer.
- Identity Layer, which provides a digital identity (public and private keys) for the PGUI to sign and send the data packet to the Blockchain Access Layer.
- EMS Interface, which interacts with several Energy Management Systems (e.g. Battery Management Systems, Smart Homes Devices, Power Plant Management Systems).
- Meter Interface, which interacts with several meter technologies (e.g. Low Voltage and Medium Voltage Meters).

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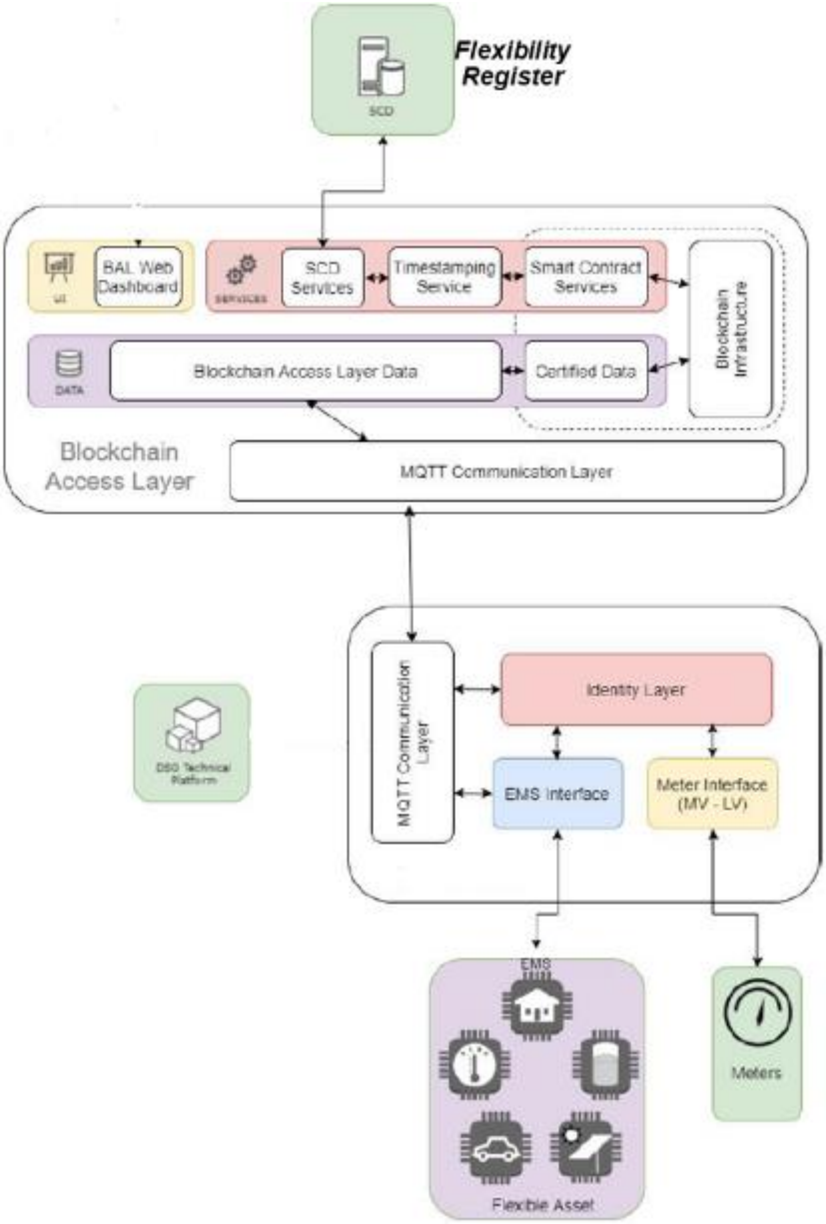

Figure 28 - PGUI (areti) Reference architecture

1. The Data Layer offers connectivity to the Blockchain Access Layer, BAL, this communication channel allows the PGUI to send signed measurements gathered from the meters to the Blockchain Access Layer and, at the same time allowing Operators (e.g. the BSP, the DSO) to send activations to Flexible Assets through the EMS interface.
2. The connectivity to the Blockchain Access Layer, also provides service level functionalities such as Over The Air upgrades, certificate rotation, configuration management and system health reporting.
3. The Identity Layer is the functionality that signs data packets through the identity keys of the PGUI. Signatures will be verified by Blockchain Access Layer (BAL), before forwarding them to the Flexibility Register.

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4. The EMS Interface receives activation commands from the BAL, then make them available to local assets through local interfaces: the communication protocol used depends on the EMS installed at customer's side:

    - Industrial application: In this environment, the communication protocol is Modbus RTU or Modbus TCP.
    - Energy Community application: In this environment, the communication protocol is REST API or MQTT.
    - Electric Vehicle Charger application: The communication protocol is REST API or Modbus RTU or Modbus TCP.

The PGUI communicates with the Smart Meter in the three different ways explained below, that can be activated in the configuration phase of the device.
The related communication channel depends on the electric meter's capabilities:

- Smart Meter (for Medium Voltage customers): integration through an Industrial Protocol (Modbus TCP or Modbus RTU).
- Smart Meter 2G (for Low Voltage customers): integration through a powerline interface (PLC-C as known as Chain 2).
- Smart Meter 1G (for Low Voltage customers): integration through additional meters (smart devices capable of retrieving the necessary electrical parameters).

The Meter Interface reads metering data, and then, through the MQTT Client, sends the Meter Data signed by the Identity Layer to the Blockchain Access Layer.

5.1.3. Requirements and technical specifications

Operating at the intersection of cutting-edge technology and functional requirements, the PGUI adheres to stringent technical specifications and requirements tailored to its operational environment. Key among these specifications are the communication protocols governing interaction with external entities. Depending on the application context, communication protocols such as Modbus RTU, Modbus TCP, REST API, and MQTT are employed to ensure seamless data exchange between the PGUI and the respective EMS or metering devices. The PGUI is architected to accommodate diverse EMS configurations and metering technologies, thereby offering scalability and interoperability across a spectrum of utility infrastructures. Additionally, the PGUI's capabilities extend beyond mere data aggregation, encompassing real-time data acquisition, blockchain certification, and bi-directional communication with third-party entities such as DSOs, thereby reinforcing its position as a critical component within the evolving landscape of distributed energy management systems.

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5.2. PGUI e-distribuzione

5.2.1. Overview

The PGUI (Power Grid User Interface) device system enables communication and interaction between three types of devices, each specialized in managing specific functionalities The goal is to allow stakeholders to actively participate in the flexibility market of electricity grids:

- **QEd:** This device implements the DER Gateway, which is a communication interface between Distributed Energy Resources (DERs) and BeFlexible systems. The QEd provides communication services to CCIs (Central Plant Controllers) and Chain3Emulators, enabling controllability and observability functionalities at both medium (MT) and low (LV) voltage levels.

- **CC**I: Acronym for "Controllore Centrale d'Impianto" (Central Plant Controller), the CCI is a device standardized by the CEI (Comitato Elettrotecnico Italiano) according to CEI 0-16 Annexes T and O[11]. Installed at the delivery point of medium-voltage DERs, the CCI allows Distribution System Operators (DSOs) and Balance Service Providers (BSPs) to monitor and control DERs through a standard interface compliant with the IEC 61850 TLS standard.

- **Chain3Emulator:** This device acts as a communication gateway, enabling a point-to-point connection between low-voltage (LV) meters and QEd by the use of Chain3 channel. It also provides an RS232 communication channel that can be used by BSPs to control LV systems.

5.2.2. Architecture

Interaction between BSP and BeFlexible

The BSP interacts with the BeFlexible system exclusively through an API. After a registration phase, the BSP will be authorized and connected to the plants under its control and will be able to interact with them and obtain a data stream that will update it in real time on the status of the plants. It will also be able to send requests to activate controllability functions and obtain the result and status.

[11] https://mycatalogo.ceinorme.it/cei/item/0000018527/?sso=y

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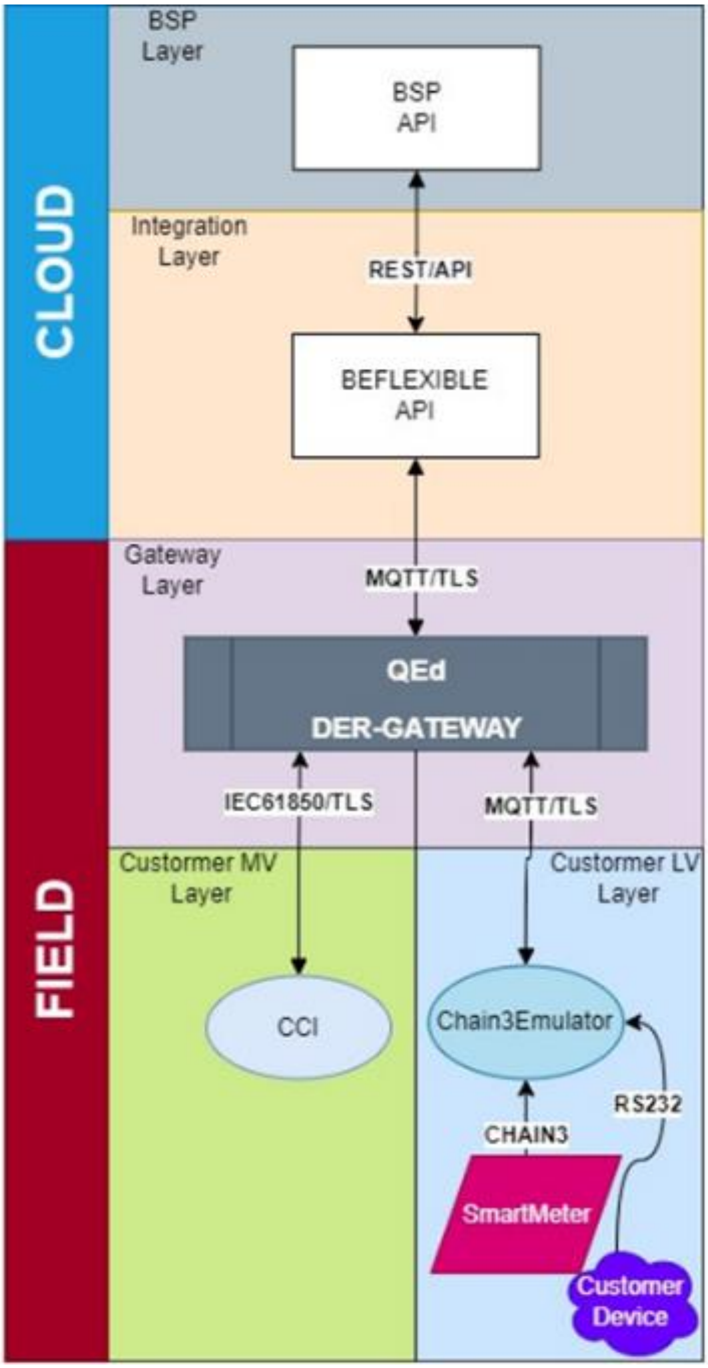

Figure 29 - PGUI (e-distribuzione) architecture

Use Case:
The BeFlexible project provides the following Functionalities:

1. MV Observability:

- The CCI sends the following measurements to the DER-Gateway via the IEC 61850/TLS protocol:
    - Active power (P) and reactive power (Q) relative to the PoD

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  - Active power (P) produced by the plant, aggregated by generation source.
  - Active power (P) produced by individual generation units.
  - General plant device status.
  - Status of the unit device to identify the status of the individual generation unit.
- The DER-Gateway converts the received information into the IEC 61850/TLS protocol and forwards it to the BeFlexible system using the MQTT protocol.
- The BeFlexible system receives all measurements from the various DER-Gateways and forwards the relevant measurements to the various BSPs via the shared APIs.

2. LV Observability:

- The Chain3Emulator sends the following information to the DER-Gateway via the MQTT protocol every 20 seconds, obtained via the Chain3 protocol from the SmartMeter:
  - SmartMeter Clock.
  - SmartMeter Status Word.
  - Instantaneous Imported Power unit Watt.
  - Instantaneous Exported Power unit Watt.
- The DER-Gateway receives the information from the various Chain3Emulators and forwards it to the BeFlexible system using the MQTT protocol.
- The BeFlexible system receives all measurements from the various DER-Gateways and forwards the relevant measurements to the various BSPs via the shared APIs.

3. MV Controllability:

- In addition to the observability functions (PF1), the CCIs to be provided for the BeFlexible project must also include the controllability functions (PF2 and PF3) provided for by the CEI 0-16 standard. In particular, the experimentation will only test participation in the Dispatching Services Market with the function of receiving an active power (P) setpoint from the BSP.

4. LV Controllability:

- The BSP, through its management system, forwards messages to the BeFlexible system, through the available APIs, to be dispatched to the devices used for LV controllability.
- The BeFlexible system receives the message to be dispatched to the plant, identifies the DER-Gateway that manages the communication to the plant's Chain3Emulator and forwards the content to it.
- The DER-Gateway forwards the message to the Chain3Emulator by MQTT protocol.
- The Chain3Emulator forwards the message on the RS232 port and returns a delivery confirmation message (ACK) and any messages received on the same port to the system.

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5.3. PMU

5.3.1. Overview

PMUs are innovative measurement devices that offer high time resolution and accuracy in grid monitoring. They are particularly noted for their ability to measure the magnitude and phase angle of voltage or current signals, synchronized via GPS. The implementation involves integrating PMU data into the Distribution Management System (DMS) to improve real-time operational standards. The PMU's application aims to upgrade metering infrastructure, reconcile PMU data with conventional measurements, and enhance the precision of network state calculations. This integration is part of a larger effort to increase monitoring and observability at various nodes of the distribution grid.

By integrating PMU data into DMS, grid operators gain a more detailed and real-time view of the grid's performance. This enhanced observability is crucial for ensuring grid stability and optimizing the flow of electricity.

In detail, the installation of PMUs at selected buses ensures the upgradation of the overall metering infrastructure of the network, since it records synchronized measurements of bus voltage phasors as well as several line current phasors—all of which are independent of each other and count as individual measurements. Their utilization via the State Estimation Tool is a challenging task due to a) the discrepancies in update rates between conventional and PMU measurements, and b) the provision of current measurements which often lead to various numerical problems. The goal is to ensure that the integration of PMU data will be smooth, and all the aforesaid problems will be circumvented.

Given that the network model (topology) is known with a good degree of certainty, the state estimation tool ensures that the network is observable based on the available measurement set, reconciles the PMU data with the conventional measurements, and, subsequently, calculates the estimated state vector, that is, the voltage magnitudes and angles of all network buses. Given the successful integration and use of the PMU data in the SE tool, the overall performance of the SE tool will be enhanced; the network state will be calculated with increased precision compared to conventional-measurements-only scenarios, and high-quality real-time operational standards for distribution management applications will be met.

5.3.2. Architecture

The architecture describes a process involving the measurement, processing, and utilization of electrical wave data within a power system. The step-by-step explanation of the flow is given as, Figure *31*:

- **Electrical Waves:** The process begins with the electrical waves that are present in the power system. These could be the sinusoidal voltages and currents flowing through the power grid.

- **Phasor Measurement Unit (PMU):** These electrical waves are then fed into a Phasor Measurement Unit. A PMU is a device that measures the electrical waves to determine the magnitude and phase angle of the electrical power grid using a common time source for synchronization.

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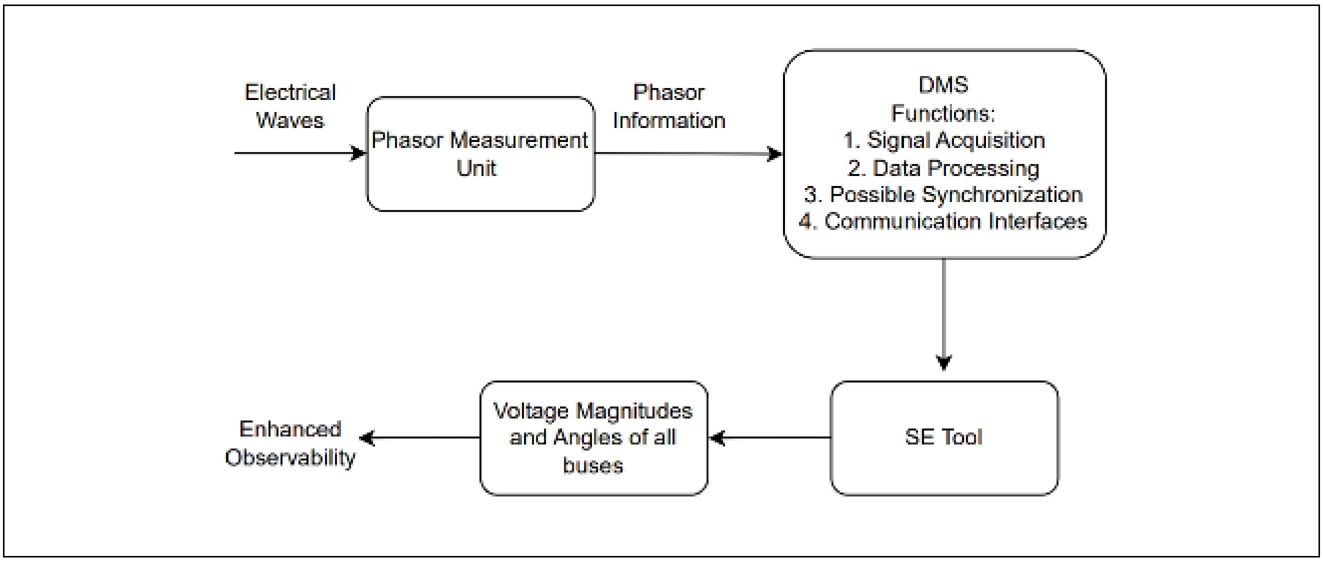

Figure 30 - PMU process flow chart

- **Phasor Information:** The PMU outputs phasor information, which includes the magnitude and angle of the sine waves (phasors) in a synchronized manner, allowing comparison across the grid.
- **DMS Functions:** This phasor information is then used by a Distribution Management System (DMS), which can perform several functions.
- **SE Tool:** The output of the DMS functions is then passed to a State Estimation (SE) tool. State estimation is a method used in electrical power systems to deduce the state (voltages and phase angles at various points) of the electrical grid from the available measurements.
- **Voltage Magnitudes and Angles of all Buses:** The state estimation process yields the estimated voltage magnitudes and angles at all buses in the power system. A bus in this context is a node where one or more lines come together in a power system.
- **Enhanced Observability:** Finally, the output of the SE tool is used to achieve enhanced observability of the power system. This means that operators have a clearer picture of the state of the power system in real-time, allowing for better control and management, potentially leading to more reliable power delivery and quicker response to system disturbances.

The description of the flow chart for the architecture of PMU is given below, Figure 31:

- **Input Signal:** The flow starts with the input signals, which are the electrical waves (current and voltage) from the power grid.
- **Analog-to-Digital Conversion (ADC):** These Analog electrical signals are converted into digital signals by the ADC within the PMU.

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- **Signal Conditioning:** The digital signals might undergo signal conditioning, which can include filtering and amplification to prepare them for accurate measurement.

- **Phasor Calculation:** The conditioned digital signals are then used to calculate the phasors, which represent the magnitude and phase angle of the electrical waves.

- **Time Synchronization:** Each phasor is time-stamped using a common time reference, usually provided by a GPS signal, to synchronize the measurement with other PMUs.

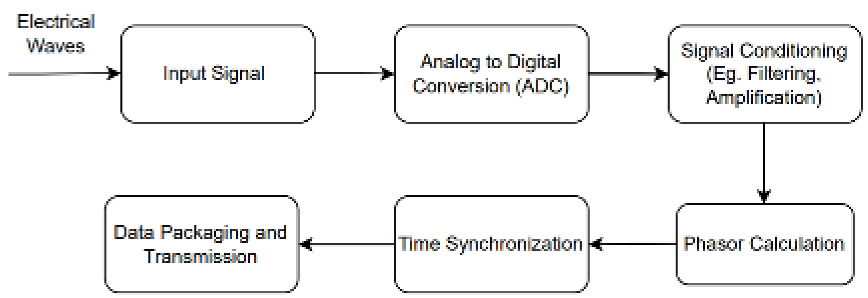

Figure 31 - PMU architecture

- **Data Packaging:** The time-stamped phasors are then packaged into a data frame, including identification and status information.

- **Data Transmission:** These data frames are transmitted to a central location, such as a DMS or control center, for further analysis and use in grid management.

5.3.3. Requirements and technical specifications

The PMU foresees the participation of actors as given below:

- **DSO (Distribution System Operator)**: Oversees the integration and management of PMUs within the distribution network.

- **Distribution Management System (DMS)**: Software system that receives and processes data from PMUs.

The Phasor Measurement Unit (PMU) plays a pivotal role in enhancing grid observability for both low and medium-voltage networks. Here's a detailed outline of the whole PMU process:

- **PMU Installation and Integration:**

The Distribution System Operator (DSO) is responsible for installing the PMU and starting communication with the Distribution Management System (DMS).

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PMUs are installed in secondary substations and at selected buses within the distribution grid.

- **PMU Functions and Data Collection:**

PMUs measure the magnitude and phase angle of voltage or current signals, synchronized via the Global Positioning Satellite (GPS) system.
These devices read data from field sensors and are involved in real-time data collection.

- **Data Transmission and Utilization:**

PMUs send the collected data to the DMS.
The data is used for real-time operational standards and grid state estimation, improving the accuracy and observability of the grid.

- **Challenges and Objectives:**

Integrating PMU data into the grid network involves overcoming challenges related to discrepancies in update rates between conventional and PMU measurements and the provision of current measurements, which often lead to numerical problems.
The goal is to ensure the smooth integration of PMU data to enhance the overall metering infrastructure and grid observability.

Characteristics of PMU:
PMUs are noted for their high time resolution and accuracy, crucial for grid observability.
They are described as open-source, low-cost devices that are relatively easy to integrate into the grid infrastructure.

The technical specifications and requirements in detail regarding PMU are given below:

Technical Specifications

Sampling Rate: PMUs should have a high sampling rate, typically 30-60 samples per electrical cycle, to capture detailed waveform data.
Accuracy: The accuracy of PMUs should be within the limits defined by IEEE standards, ensuring precise voltage and current phasor measurements.
Time Synchronization: GPS-based time synchronization is essential, with a time accuracy of less than 1 microsecond to ensure data coherency across the grid.
Data Resolution: PMUs must provide high-resolution data, capturing both magnitude and phase angle of the electrical phasors.
Frequency Measurement: Capability to measure grid frequency with high accuracy, including the detection of frequency deviations.

Communication and Data Transmission

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Communication Protocols: Support for standard communication protocols like IEC 61850, IEC 60870-5-104, and DNP3 for interoperability with various grid systems.
Real-Time Data Transmission: The system should facilitate real-time data transmission to the Distribution Management System (DMS) for immediate analysis and action.
Data Security: Robust cybersecurity measures must be in place to protect sensitive grid data during transmission and storage.

Compatibility and Integration

DSO and DMS Integration: PMUs should seamlessly integrate with existing Distribution System Operator (DSO) infrastructures and Distribution Management Systems, ensuring that data is accurately reflected in grid control strategies.
Scalability: The design should allow for scalability, enabling the integration of additional PMUs as the grid evolves.

Installation and Operational Standards

Installation Requirements: Guidelines for the strategic placement of PMUs to maximize grid observability, considering factors like critical grid points and areas prone to voltage fluctuations.
Maintenance and Reliability: Maintenance protocols should be established to ensure ongoing reliability and accuracy of PMU measurements.
Compliance: Adherence to regional and international standards for grid monitoring equipment, including safety and environmental regulations.

Additional Features

Event Recording: Capability to record and timestamp significant grid events for post-event analysis and grid improvement strategies.
Adaptability to Grid Conditions: The ability to adapt measurement and reporting criteria based on changing grid conditions, like load variation and fault occurrences.

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6. Customer Engagement Strategies

The South-Mid EU Demo developed in the BeFlexible WP4 is strongly based on the national projects RomeFlex and Edge developed in response to the ARERA Resolution 352/2021[12], part of the users currently involved in the national projects will also take part in BUC04 "Long-term distribution grid congestion management" and BUC06 "Short-term congestion constraints forecasting and management for local flexibility service activation" activations planned in WP4. This chapter of the deliverable analyses the customer engagement strategies and characteristics of the user involved in the pilots 1.1 Rome (Areti), 1.2 Foggia and Benevento (Enel) and 1.3 Cuneo (Enel), by describing the area of the grid which will take part in the project BUCs, the characterization of the User involved in the different BUCs tested and finally the engagement strategies that led to the user involvement in the pilots.

6.1. Description of the Demo area

Pilot 1.1 Rome

Areti manages the electricity distribution network in the municipalities of Rome and Formello.- The electricity grid managed by areti is at the service of a vast metropolitan area rich in historical and cultural importance, has specific characteristics that are difficult to find in other cities. In addition to the presence of numerous and important archaeological sites and vast protected natural areas, you must also consider the particularly complex urban context. The city of Rome is divided in 15 Municipalities, in turn divided in 155 urban areas. The urban areas were founded in 1977 with statistics, planning and territorial management purpose, following uniformity urban criteria. The boundaries are identified along the continuity solutions marked on the urban territory as shown below in Figure 32:

[12] https://www.arera.it/atti-e-provvedimenti/dettaglio/21/352-21

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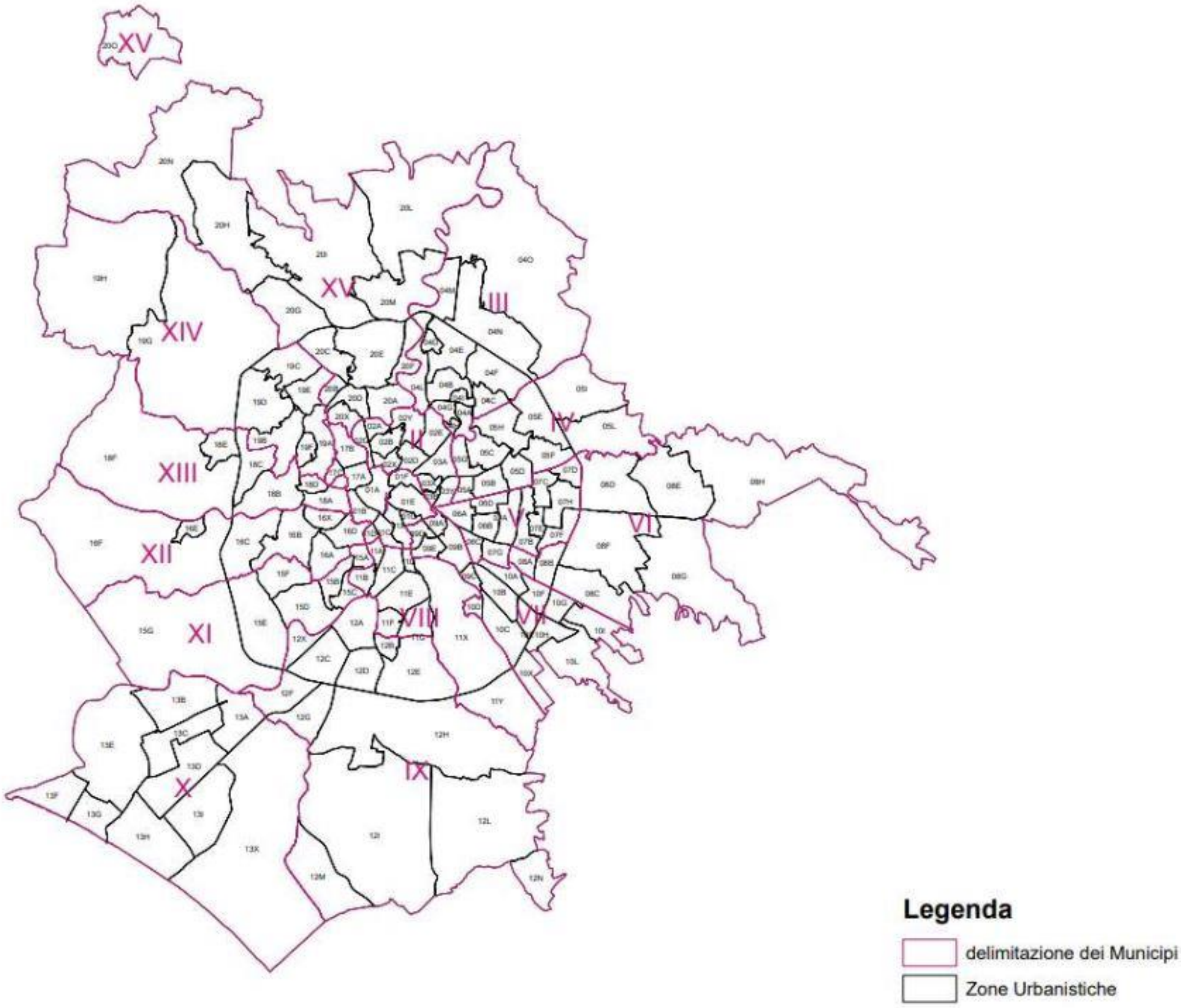

Figure 32 - Areti municipalities distribution grid

The electricity distribution grid extends over the metropolitan city of Rome, for about 31,000 km and can power about 2.9 million residents. Currently, the company distributes electricity to over 1.6 million electricity users in the municipalities of Rome and Formello. The energy fed into the grid in 2022 amounted to 10.02 TWh, corresponding to 2.091 MW of peak annual power output (recorded on 25 July 2022 at 15:00)[13].

The Pilot 1.1 area will be extended beyond the Rome metropolitan area thanks to the special involvement of four companies from the Acea S.p.A. Integrated water distribution service for the testing of BUC11 "Capitalizing on flexibility available by leveraging on water distribution network assets". For this test will be involved multiple Italian regions like Lazio, Campania and Tuscany.

[13] Areti Piano Sviluppo 2023 https://www.areti.it/content/dam/acea-areti/documenti/area-istituzionale/attivita/piano-di-sviluppo/Piano_di_Sviluppo.pdf

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Pilot 1.2 Foggia and Benevento and Pilot 1.3 Cuneo

E-Distribuzione is the largest DSO in Italy. It provides its services to over 31 million customers, spread across more than 7,400 municipalities. The industrial activity of electricity distribution includes all operations related to the operation, maintenance, and development of infrastructure in Medium and Low Voltage, as well as commercial activities connected to service delivery. From an infrastructure standpoint, the electrical system managed by the company includes HV/MV Substations, MV power lines, MV/LV Substations, LV power lines, and energy metering devices (smart meters).

The pilot 1.2 and 1.3 areas have been defined in the framework of "EDGE project"[2]: in a portion of the electrical network of the areas of Benevento, Cuneo and Foggia, Figure 33, namely "areas of interest", a local flexibility market has been established, responding to ARERA Resolution 352/21[12].

The extension of the network in the areas of interest consists of about 30 HV/MV Substations, 20.000 MV/LV Substations, 650 MV feeders.

Figure 33 - Position of the areas of Benevento, Cuneo and Foggia

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6.2. User Characterisation

Based on the framework described in D2.2 of BeFlexible Customer Engagement Strategies. Each pilot will frame and [14]summarise the customer involved taking into consideration the project activities in which they are involved and the devices with which they will be equipped.

Pilot 1.1 Rome

RomeFlex BSPs:
The RomeFlex project[3] represents a major advance in the organisation of energy flexibility services. All customers, whose assets in low or medium voltage are in the areas served, will be able to modulate their consumption and energy production taking part in the project, offering their services of flexibility to Areti. The project provides the possibility for BSPs and all other stakeholders to bid and provide flexible services during specific time slots. RomeFlex uses blockchain technology to guarantee transparency and immediate certification of all economic transactions of settlement of the service and technical reporting of the provision of the service itself (thanks to the Smart-Contracts implemented). The BSPs that will provide the required flexibility services will be remunerated with an economic value depending on the service rendered and possibly, when provided, also for the availability to provide the service.

As mentioned before BSPs in Romeflex act as an intermediary between the DSO and the DERS by identifying the load and/or generation of its customer portfolio needed to increase or decrease the energy use in the grid. Through their systems, customers can make their flexibility available through modulation plans, as a result, the load reduction or increase is used by the DSO for grid balancing. In return, customers receive remuneration from the BSP for the modulation performed.

The BSP in RomeFlex provide energy resources based on highly differentiated DERS ranging from Electric vehicles, Residential buildings, Industrial plants and Public Buildings spread across the Rome grid. Every PoD of the BSPs participating in RomeFlex are equipped with a PGUI device.

Platone Residential Users:
The project BeFlexible acted as a natural continuation of the experimentation that areti developed in the project PlatOne[15] concluded on August 2023. During the course of the project, Platone Areti successfully engaged 11 residential users to actively participate in the project, the users selected were initially engaged through the collaboration of ENEA and Acea Energia, as users that were already interested in the topics of sustainability, ecology and energy efficiency. The Users in order to participate in the experimentation were equipped with various devices depending on the characteristics of the habitations:

[14] https://beflexible.eu/wp-content/uploads/2023/12/BeFlexible-D2.2-Customer-Engagement.pdf
[15] https://www.platone-h2020.eu/

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a) Smart Meter 2G: 2nd generation smart meters able to measure by high frequency (up to 1s) electrical quantities at the grid connection point (PoD) and make them available in (close)real-time to PGUI (by means of Power Line communication technology).
b) PGUI: it certifies and makes available smart meter measurements to customer devices and to Platone platforms; moreover, it receives the Set-point to be activated by the customer activation system (e.g. EMS, Storage, EV charger etc.) to deliver flexible service.
c) App: a smart-device application designed to perform several functions to monitor Smart Meter measurements, monitor flexibility service delivery, set available flexibility etc.
d) Micro photovoltaic system: a PV generator system with Power up to 300W.
e) Storage system: a domestic storage system able to modify its operation (charging and discharging) according to pre-set algorithms or external setpoint.

Only installation of equipment at points a), b) and c) were mandatory for the demo; the others were optional since they can be installed based on customer preferences and house features (e.g. sun exposition, available space etc.).

During September 2023 and after the ending of the Platone project, Areti prepared an application form for the onboarding of the Platone Residential Users in BeFlexible. The form prepared after an introduction to the project objectives and a general description of the Rome pilot, asked the users if they were willing to continue the experimentations started on the Platone project within the BeFlexible project. Out of the 11 residential users previously involved in the project 8 decided to continue the experimentations within the BeFlexible project.

Acea S.p.A. Integrated Service Water distribution companies:

The pilot 1.1 in Rome will also test the application of flexibility provisions to the water distribution services through the implementation of BUC 11 "*Capitalizing on flexibility available by leveraging on water distribution network assets*". To implement this business use case areti successfully involved four companies controlled by Acea S.p.A. operating in the integrated water service sector. The companies involved operate in different Italian Regions and are:

- ATO2: Province of Rome, Lazio Region.
- ATO 5: Province of Frosinone, Lazio Region.
- GORI: Province of Napoli and Salerno, Campania Region.
- Acquedotto del Fiora: Province of Grosseto and Siena, Tuscany Region.

Pilot 1.2 Foggia and Benevento and Pilot 1.3 Cuneo

Identification of the areas for the EDGE project

With the help of the EnSiEL consortium[16], e-distribuzione defined a perimeter of interest for both the pilot 1.2 (Foggia and Benevento) and Pilot 1.3 (Cuneo). The parts of the networks where the project insists were chosen based on the evidence of a rapid growth of new connections and the possibility of using effectively the flexibility services. The selected areas include urban areas of medium and small size, rural areas as well as industrial and mountainous ones. Each area of interest is mainly identified by a need in terms of power to provide as flexibility for a given amount of time (or forecasted number of activations) and with a "direction", i.e. increasing/decreasing power consumption/production which in turn depends on the pool of assets providing the service. Every asset electrically included in each area of interest, like Production or consumption units, storage and EV charging points, is potentially enabled to provide flexibility services. The following table 2 gives an idea of the total power available as consumption/production for each Province. Note that each area of interest is identified as an electrical portion of the grid contained in the province itself and so the amount of power available to provide services in the area will be a portion of the total amount shown below.

Table 2 - Total power available as consumption/ production for pilots 1.2 and 1.3

	Production Units (Nominal Power)								Consumptions Units			Total Units	
	Wind	PV	Idraulic	Thermal	Others	**LV**	**MV**	**TOT**	**LV**	**MV**	**TOT**	**LV**	**MV**
	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	N°	N°
BENEVENTO	209	693	36	98	1	337	701	1.038	3.612	1.778	5.390	146.636	385
FOGGIA	216	2.230	2	80	4	598	1.935	2.533	5.616	2.058	7.674	375.324	1.105
CUNEO	8	1.769	756	695	19	818	2.429	3.247	5.071	5.084	10.155	427.156	2.025

Both the number and the power of the production/consumption units are expected to grow, in particular for production units, actively supported by a growing number of grid-connection requests. Most of the time, new PV plants come with a storage unit making them more suitable to offer flexibility services. With the growing number EV charging points, there is also a growing number of Charging Points operators (CPO) potentially interested to offer flexibility services. The numbers break down as follows:

Table 3 - CPO flexibility services for pilots 1.2 and 1.3

	EV charging points	CPO	Total Power
	N°	**N°**	**kW**
BENEVENTO	32	11	1.119
FOGGIA	97	26	5.061
CUNEO	159	33	7.206

[16] https://consorzioensiel.it/consorzio/chi-siamo/

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E-distribuzione planned to acquire flexibility services, intended as bi-lateral contracts of medium/long term signed with the Flexibility Providers (FP), through competitive auctions held on a third-party platform, i.e the market platform, called Picloflex. On Picloflex website[17] there is a visual representation of the areas of interest with all the details of the competition available to the FP. The platform is indeed interposed between E-distribuzione and the FP: to participate to the competition for one or more area of interest, each FP register their assets directly on Picloflex. The assets, if "electrically" included in the area of interest, may be eligible for offering flexibility services as single or as aggregate: a FP indeed can choose to pool their assets to satisfy requirements that would not be met by a single asset for a chosen area of interest. For each asset participating, it is necessary for it to have a smart meter of new generation so to correctly address the amount of energy delivered when called to offer a service. On the other side, it is up to the FP to choose how to control the assets.

The Beflexible pilots, leveraging the EDGE[2] FPs on voluntary basis, would test the direct observability and activation of flexibility services using a different Power Grid User Interface (PGUI) for MV and LV resources. All the Flexibility Service Providers (FSPs) contracted on the useful time period could be able to participate to the Beflexible demo.
The deployment of the e-distribuzione pilots mainly foreseens the involvement of Gridspertise as technological provider.

6.3. Engagement Strategies

Pilot 1.1 Rome

RomeFlex BSPs:
Areti hosted various webinars for the involvement of BSPs before the public and the effective launch of RomeFlex activities in February 2024. The webinars were fundamental to share with the BSPs the message and the importance of their active role and participation in the project. The participation of BSP was regulated through two open sessions for the definition of Local long-term market trading session (LFM), the first one held in November 2023 was used to test the overall system of RomeFlex, while the second one is scheduled for the summer of 2024 established the final version of RomeFlex. The onboarding of the participating BSPs on the BeFlexible project was done by creating a linked dedicated project webpage on Areti's website[3], so when a BSP applies for participation in RomeFlex, it is also inserted in the experimentations carried out in pilot 1.1 of BeFlexible.

Acea S.p.A. Integrated Service Water distribution companies:
The involvement of the 4 water distribution service companies from Acea S.p.A., which manages a great portion of the water distribution service of mid-south Italy was pursued through different stages. First, the companies were contacted through a formal request of interest to participate in the project, this phase had the objective of presenting the project BeFlexible, the context of Horizon EU experimentations and the general objective areti was pursuing in pilot 1.1. Once the companies signed the request to participate in the

[17] https://www.piclo.energy/italy

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project, areti had to sign a legal Non Disclosure Agreement (NDA) with each company for the formal exchange of data and sensible information among all parties participating in the experimentation. Through this stage, Areti had online webinars attended by all the water distribution companies presenting successful case studies of foreign water distribution companies implementing the provision of flexibility through their services. This was a key factor in attracting the interest of the water distribution companies and of Acea S.p.A., demonstrating the relevance and the possibilities deriving from approaching the field of the flexibility energy market from the water distribution point of view.

Pilot 1.2 Foggia and Benevento and Pilot 1.3 Cuneo

E-distribuzione hosted some webinars, one on January the 20th 2023 during the public consultation phase and two in order to meet the interested parties before the main competition phases on September the 12th 2023 and on February the 2nd 2024. During the webinars it was explained the goal of the project from e-distribuzione point of view and it was presented the Picloflex platform. The webinars turned out to be very useful to answer questions common to different participants and to be then gradually published on the FAQ section of the project's website[2], which is constantly updated with new information. The onboarding of FPs on the platform, like the registration, the assets upload etc. was followed by Piclo itself. It should be noted that the interaction is always between Picloflex (the "third part") and the FPs, that manage resources as aggregators.

E-distribuzione has also a dedicated web page on its website, that contains all the technical documentation and every useful information for potential FPs and flexibility resources[2]

The program of engagement of FPs and flexibility resources naturally follows the program of the competitions defined in the EDGE project, that has been organized in seasonal phases, with the following scheme, for the year 2024 (the resources registration phase and bid phase for 'Winter 2024' season were scheduled in 2023). In particular, the competitions considered for the BeFlexible pilots are the summer ones, Figure 34.

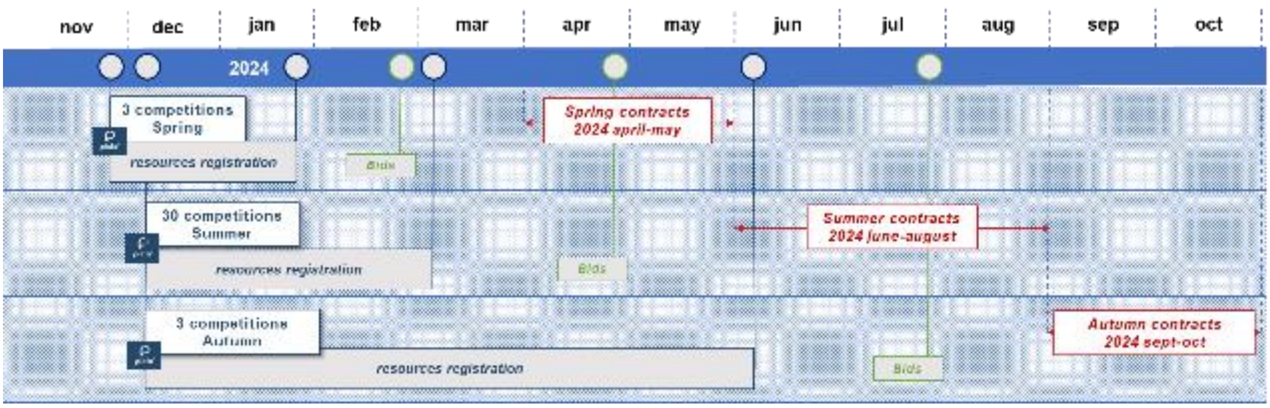

Figure 34 - Schedule of the different deadlines for the Edge project

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7. Conclusion

Leveraging on the results reported in Deliverable 4.1, this report defines the software and the hardware solutions that will be tested in the field during the demo and validation campaign of Task 4.3. Moreover, the interactions, the functionalities and the data flows between the components have been investigated to foster the involvement of the DERs in the flexibility market. Finally, Deliverable 4.2 delved into the customer engagement strategies and user characterization of the participants involved in the SUCs and national pilot projects Edge and RomeFlex.

The reference architecture, defined at the beginning of the document, sets a crucial milestone in the coordination mechanism TSO-DSO, simplifying the resources registration phase and the interaction during the market session, to avoid double paying or local grid violation due to GFM movements. Beyond the procurement phase, the South-Mid EU Demo, as requested in the SUC reported in - Business and System Use Cases Italian PilotsTable 1, treats the main steps of the flexibility market, testing the activation and settlement through innovative devices installed at the customer's property to foster the involvement of the small end user in the flexibility market. Concerning the market phases, all the platforms (Derms, DSO Technical Platform, CBP, Flexibility Register and Market Platform) and all the devices employed in the architecture have been described in detail.

To increase the validity of the pilot, several customers involved in the RomeFlex and EDGE project are involved in BeFlexible. Furthermore, in pilot 1.1 will be installed and tested the PMU a device developed by RWTH to improve the grid observability, and to better perform the state estimation tool. Finally, to implement the flexibility cross-sectorial topic, the flexibility potential of the water distribution grid will be assessed to evaluate the service that these assets can provide in several landscapes (urban, rural, semi-urban).

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[14] Beflexible D2.2 link

[15] https://www.platone-h2020.eu/

[16] https://consorzioensiel.it/consorzio/chi-siamo/

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9. Annex 1 Business requirements

9.1. Resource Registration & Prequalification

9.1.1. Asset registration

The resource registration process will be divided into:

- registration for the Local Flexibility Market (LFM)
- registration for the Global Flexibility Market (GFM)

For the LFM the BSP registers the asset on the FR, that will forward the information set to the systems of the relevant DSO, so it is informed on of every single GPC, connected to his distribution grid.

The resource information is then shared by the FR to the CBP by using the *Register Flex Resource* service, subsequently the CBP will forward the information to Terna. The sets of information shared through the service is detailed in the table below:

Table 4 - Register flex resource service

INFORMATION	DESCRIPTION	NOTES
BSP Code	Identification Code of the BSP represented by P.IVA	To be determined if EIC Code can be used or it should be defined a new standard for the ID code.
Grid Connection Point ID	Code identifying the Grid Connection Point	
Grid Connection Point Type	• Consumption • Generation • Mixed	
Market Type	Define the type of market for the flexibility resource • Global (Mark yes:no) • Local (Mark yes:no)	Participation in one market rather than another is signaled by a yes/no flag
Location	ISTAT code associated to the resource	
Generation Unit ID	Code of the Generation Unit.	

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Contracted Power	The power level made available by the resource for the power supply	
Maximum Flex Up	Flexible upward power	
Minimum Flex Down	Flexible downward power	
Grid Voltage Level	• The grid voltage level communicated by the BSP must be included in the list below: • AAT 380 kV • AAT 220 kV • AT 150 kV • AT 120-132 kV • AT 40-90 kV • MT 23-39 kV • MT 17-22 kV • MT 11-16 kV • MT 1-10 kV • BT	
Flexibility Asset Technology Type	Technology that enables the resource to provide flexible power. The technology communicated by the BSP must be included in the list below: • Accumulo elettrochimico • Eolico • Solare • Geotermico • Prelievi utenza BT • Prelievi utenza AAT/AT/MT • Prelievi stazioni di ricarica per EV • Altro	
DSO EIC Code	EIC Code for the relevant DSO on whose network the resource belongs	

The information can be always updated by the BSP using the update functionalities.

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The information related to the static validation of the resource on the LFM, carried out by the DSO, is then communicated through the FR to CBP, which will subsequently share it with Terna. The details of the static validation process are discussed in the next section.

For the GFM the BSP registers the asset on the CBP, by using the *Register Flex Resource service* with the same sets of information described in the previous table. CBP transfers the information to Terna and at the same time to the FR, starting the asset validation phase from the relevant DSO. The details of the static validation process are discussed in the next section.

9.1.2. Asset validation

Once the DSO acquire information about every single Grid Connection Point (GCP) it can start the Static Validation Process whereby it is confirmed whether a given BSP can use a given resource in the market and the verified amount of flexible power.

The DSO performs the Static Validation directly on its Flexibility Register profile. The information are then forwarded to Terna, by using *Update Static Resource Constraints* service of the CBP. The relevant information for static validation are listed as following:

- Distribution Grid Location ID
- Measurement Treatment
- Static Traffic Light, composed by a colour codification (Up/Down), validated flexible power (Up/Down), motivation.

The set of information to be communicated by the DSO for the Static Validation Process is detailed in the table below:

Table 5 - Update static resource constraints service

INFORMATION	DESCRIPTION	NOTES
Grid Connection Point ID	Code identifying the Grid Connection Point	
BSP ID Code	Identification Code of the BSP represented by P.IVA	
Distribution Grid Location ID	DSO Perimeter ID representing the individual node/element/aggregate of nodes in the distribution network to which the distributed flexibility resource refers.	Proposed format for Distribution Grid Location ID: • DSO EIC Code (16 elements) • ISTAT code for the municipality (6 elements) • A predefined number

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Distribution Grid Location Type	Type of DSO Perimeter from the list: • _CS in case of Secondary Substation • _AG in case of aggregates of DSO elements • _LN in case of LV line	
Static Traffic Light Colour	A predefined colour codification for a Go, Go-if, No-Go system: • Green when there is no limitation on the use of the resource • Yellow for limitations on the use of the resource or for reporting inconsistencies in the asset details or technical data declared by the BSP • Red in case of invalid resource The Traffic Light Colour must be defined both for upward and downward flexible power.	STL colour is correlated to the DSO Validated Upward/Downward Power, as described in the following rules: • Green STL: $DSO\ Flex\ P = BSP\ Flex\ P \Rightarrow Green\ STL$ • Yellow STL (Upward Power): $DSO\ Flex\ Pup < BSP\ Flex\ Pup \Rightarrow Yellow\ STL$ • Yellow STL (Downward Power): $DSO\ Flex\ Pdown < BSP\ Flex\ Pdown \Rightarrow Yellow\ STL$ • Red STL: $DSO\ Flex\ P = 0 \Rightarrow Red\ STL$
DSO Validated Upward Power	The amount of modulating power the DSO can accept the GCP for, in the upward direction.	The DSO Validated Flexible Power is a value smaller than or equal to the value declared by the BSP, but never higher. The DSO Validated Flexible Power is correlated to STL Colour, as described in the following rules. • Green STL: $DSO\ Flex\ P = BSP\ Flex\ P \Rightarrow Green\ STL$ • Yellow STL (Upward Power): $DSO\ Flex\ Pup < BSP\ Flex\ Pup \Rightarrow Yellow\ STL$ • Red STL: $DSO\ Flex\ P = 0 \Rightarrow Red\ STL$
DSO Validated Downward Power	The amount of modulating power the DSO can accept the GCP for, in the downward direction.	The DSO Validated Flexible Power is a value smaller than or equal to the value declared by the BSP, but never higher. The DSO Validated Flexible Power is

		correlated to STL Colour, as described in the following rules. • Green STL: $DSO\ Flex\ P = BSP\ Flex\ P \Rightarrow Green\ STL$ • Yellow STL (Downward Power): $DSO\ Flex\ Pdown < BSP\ Flex\ Pdown \Rightarrow Yellow\ STL$ • Red STL: $DSO\ Flex\ P = 0 \Rightarrow Red\ STL$
Motivation	The motivation related to the choice of traffic light colour. In the case of a yellow traffic light, the motivation is useful to indicate any inconsistencies in the personal or technical data declared by the BSP. In the case of a red traffic light, the motivation is useful to clarify the reason why the resource cannot participate in the market.	
Measurement treatment	• Hourly treatment • Non-Hourly measurments • Hourly measurements not available	If the field value is "hourly measurements not available" both STL flags should be red

At this point in the process, the resource is qualified and ready to be associated with a specific aggregate.

9.1.3. Product prequalification

At this stage, the BSP will have to create an aggregate and associate to the aggregate a number of resources, previously registered and validated, greater than or equal to one. The BSP will use the FR to register an aggregate for LFM and the CBP to register an aggregate for GFM.

During the registration of an aggregate for the LFM the BSP will upload the relevant aggregate information on the FR. The information that the Local BSP shares by using these functionalities through the Flexibility Register will be always forwarded to CPB by using the *Register Resource Group* service. Then the CBP forwards the information to Terna.

For the registration of an aggregate for the GFM the BSP will use the *Register Resource Group* service on the CBP and the information will be forwarded to Terna.

The set of information for the aggregate registration both for LFM and GFM are detailed in the table below:

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Table 6 - Register resource group service

INFORMATION	DESCRIPTION	NOTES
BSP EIC Code	BSP EIC Code that is creating the aggregate	
TSO/DSO EIC Code	TSO/DSO EIC Code that is receiving the aggregate information	
Resource Group Market Type	• Local Market • Global Market	
Resource Group Name	Name of the aggregate. For aggregates registered on the LFM, the name must begin with LA followed by a sequential numbering. For aggregates registered on the LFM, the name must begin with LA followed by a sequential numbering.	
Aggregation perimeter	Global aggregation perimeter from the following list: • NORD OVEST TO • NORD OVEST GE • NORD OVEST BS • NORD OVEST MI • NORD EST VE • NORD EST BO • DORSALE TIRRENICA RM • DORSALE TIRRENICA NA • DORSALE TIRRENICA FI • DORSALE TIRRENICA CZ • DORSALE ADRIATICA PE • DORSALE ADRIATICA AN • DORSALE ADRIATICA BA • DORSALE ADRIATICA TA • DORSALE UMBRA PG • DORSALE UMBRA TR • SICILIA • SARDEGNA Local aggregation perimeter from the following list: TBD	To be compiled if Resource Group Market Type is “Global Market” or “Local & Global Market”.

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Minimum qualified power	Minimum qualified power of the aggregate expressed in MW	
Maximum qualified power	Maximum qualified power of the aggregate expressed in MW	
Services for Global Market	If Resource Group Market Type is "Global Market" the field has to be compiled ad following: • A = Riserva terziaria sostituzione salire • B = Riserva terziaria sostituzione scendere • C = Riserva terziaria rotante salire • D = Riserva terziaria rotante scendere • E = Risoluzione congestioni salire • F = Risoluzione congestioni scendere • G = Bilanciamento salire • H = Bilanciamento scendere It is possible communicate more than one value.	
timePower	Tempo di attivazione servizio potenza attiva.	To be compiled if Resource Group Market Type is "Local Market".
maxTimePower	Tempo massimo di fornitura servizio di potenza attiva.	To be compiled if Resource Group Market Type is "Local Market".
minTimePower	Tempo minimo di fornitura servizio di potenza attiva.	To be compiled if Resource Group Market Type is "Local Market".
startTimePower	Tempo di rampa iniziale servizio di potenza attiva.	To be compiled if Resource Group Market Type is "Local Market".
endTimePower	Tempo di rampa finale servizio di potenza attiva	To be compiled if Resource Group Market Type is "Local Market".
recoveryTimePower	Tempo di recupero servizio di potenza attiva.	To be compiled if Resource Group Market Type is "Local Market".

The information provided by the BSP can always be updated by using the correct services.

When the aggregate is registered the BSP can associate to the aggregate any GCP previously registered and validated. In the case of an aggregate registered for LFM, the BSP will enter on the FR the GCPs to be associated. The FR will then share this information with CBP using the *Register Resource in Resource Group* service which will then forward it to Terna.

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The set of information concerning the association of GCPs to an aggregate is detailed in the table below:

Table 7 - Association of GCP to an aggregate

INFORMATION	DESCRIPTION
BSP Code	The EIC Code of the BSP that is associated a GCP to the aggregate
TSO/DSO EIC Code	TSO/DSO EIC Code that is receiving the aggregate information
GCP ID	The CBP blockchain ID for the GCP to associate to the aggregate
Resource Group Name	For aggregates registered on the LFM, the name must begin with LA followed by a sequential numbering. For aggregates registered on the LFM, the name must begin with GA followed by a sequential numbering.
Resource Group ID	The CBP blockchain ID for the aggregate to which the GCP is associated

In the case of an aggregate registered for GFM, the BSP will share to Terna the information of the previous table by using the *Register Resource in Resource Group* of the CBP.

9.2. Bidding and market operations

9.2.1. Local Market results communication

When each session of the Local Flexibility Marker closes and before the TSO planning session on the Global Flexibility Market for the same delivery period starts, the DSO upload market results on its dedicated area on the FR according to the timing defined in D 4.1 Methodological report of **Figure 1 - Global (MSD) and local (LFM) planning sessions in sequence**.

The FR forwards the information to the CBP by using the *Communicate Local Market Results* service.

The set of information to be communicated by the DSO for the Local Market results communication process is detailed in the table below:

Table 8 - Communicate local market result service

INFORMATION	DESCRIPTION	NOTES
BSP Code	Identification Code of the BSP represented by P.IVA	

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Resource Group Name	Name of the aggregate. For aggregates registered on the LFM, the name must begin with LA followed by a sequential numbering. For aggregates registered on the LFM, the name must begin with LA followed by a sequential numbering.	
Resource Group ID	The Identification code of the Resource Group activated by the DSO in LFM.	
Activation Request ID	ID for the flexibility request of the DSO to witch the aggregate is selected for	
Direction	Indicates the direction of power (up, down)	
Delivery Time Interval	Delivery period for the resource group to be activated by DSO for providing the service in LFM	
Total activated quantity (Q)	Represents the total quantity activated in the LFM by the DSO	

The information is subsequently shared with Terna through the CBP.

In case an aggregate is partially selected by the DSO to procure service for LFM, the BSP can communicate which resources will be used for service in LFM so that the remaining resources are not excluded a priori from GFM.

The set of information to be communicated by the BSP to communicate the resources in the aggregate activated for LFM is detailed in the table below:

Table 9 - Information communicated by the BSP for the resources in the aggregate activated for the LFM

INFORMATION	DESCRIPTION	NOTES
BSP Code	Identification Code of the BSP represented by P.IVA	
Activation Request ID	ID for the flexibility request of the DSO to which the aggregate is selected for	

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Resource Group Name	Name of the aggregate. For aggregates registered on the LFM, the name must begin with LA followed by a sequential numbering. For aggregates registered on the LFM, the name must begin with LA followed by a sequential numbering.	
Resource Group ID	The Identification code of the Resource Group activated by the DSO in LFM.	
GCP ID	ID of the GCP part of the Resource Group and selected for the activation in LFM	

9.2.2. Dynamic Validation

During the planning phase of the Global Flexibility Market, following checks carried out on its grid, the DSO can communicate grid constraints (Dynamic Traffic Light) that limit the use of aggregate of distributed flexibility resources in the GFM in order to prevent the occurrence of grid contingencies that may be associated with Terna's use of these resources.

Considering the detected criticalities, the DSO upload the information regarding the DTL on its dedicated area of the FR.

The Dynamic Traffic Light (DTL) is expressed for a given DSO Perimeter and for each hourly delivery period of the reference day in the form of a matrix consisting of these information vectors:

- Colour codification (up/down)
- Capability (up/down)
- Motivation (up/down)

The set of information to be communicated by the DSO for the DTL communication process is detailed in the table below:

Table 10 - Information communicated by the DSO for the DTL communication process

INFORMATION	DESCRIPTION	NOTES
Distribution Grid Location ID	DSO Perimeter ID	

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DTL Validity Interval	Validity interval for the constraint communicated by the DSO	
Resolution	Time resolution for the constraints communicated: • Hourly resolution (PT60M) • Quarter-hourly (PT15M)	
Direction	The direction of power upward/downward	
DTL colour codification	Color codification expressed for each hourly or quarter-hourly delivery period of the delivery day for both the "downward" and "upward" directions: • Green when no restriction is needed on the use of flexibility resources • Yellow if restrictions on the use of flexibility resources are needed. • Red if the use of flexibility resources is not possible for the existence of criticalities	The DSO may also define DTL colour for the "upward" activation direction differently from the "downward" activation direction. In this way on the same DSO Perimeter there may coexist limitations of different nature or none depending on the activation direction considered.
DTL Capability	The actual value of the constraint associated to the DTL Colour: • Green DTL automatically implies a capability equal to a generic high enough value (9999) $Green\ DTL \Rightarrow Cap = +\infty = 9999$ • Yellow DTL $\text{Yellow DTL} \Longrightarrow \text{Cap} \neq 0 \begin{cases} P_{Up} \Leftrightarrow Cap > 0 \\ P_{Down} \Leftrightarrow Cap < 0 \end{cases}$ • Red DTL implies a capability value equal to "0" $Red\ DTL \Rightarrow Cap = 0$	The DSO may also define DTL Capability for the "upward" activation direction differently from the "downward" activation direction. In this way on the same DSO Perimeter there may coexist limitations of different nature or none depending on the activation direction considered.
Contraint motivation	The reason for the constraint is expressed.	

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The FR shares the information communicated by the DSO via the CBP using the *Create Resource Constraint* service, taking into account the following gate closures:

- In the period between 10:00 a.m. and 4:00 p.m. D-1, to provide Terna in advance for each DSO perimeter with the predefined DTL attributes (colour, capability, motivation, etc.) that can be used in the event of the absence of updated data and considered valid until they are updated by the DSO
- By 16:00 D-1, to share new attributes for the DTL (colour, capability, motivation, etc.) replacing the default ones
- To update ex-ante the DTL attributes for the future valid hours of the day of delivery (D) with the following timeframe:
    - By 23:00 D-1 with validity 04:00 - 23:00
    - By 03:00 D with validity 08:00 - 23:00
    - By 07:00 D with validity 12:00 - 23:00
    - By 11:00 D with validity 16:00 - 23:00
    - By 15:00 D with validity 20:00 - 23:00

The timing of the DTL communication and update via CBP is summarised in Figure 15**¡Error! No se encuentra el origen de la referencia.**.

In the case of DTLs communicated beyond the Gate Closure provided for by a specific GFM session, these are not discarded, but Terna will consider them in the first subsequent session for the remaining hours.

The constraint sets communicated to the TSO are then shared by the FR via CBP to the BSP

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10. Annex 2 Technical requirement

10.1. User Journey

The User Journey designed for Be Flexible consist of three different processes linked to the procurement, validation and usage of flexibility resources:

- Asset Registration and prequalification
- Product prequalification
- Bidding and market operation

The aim of the project is to allow:

- BSPs to registrate and run prequalification resources and aggregates for both Local and Global Flexibility Market
- DSOs to inform the TSO of LFM results in order to support TSO planning in GFM
- DSOs and TSO to implement coordination between the two markets by expressing the static validation of the resources for the two different market, and sharing constraint information for grid availability and unavailability to be considered by the TSO in the execution of GFM

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Be Flexible Journey for the Local and Global Flexibility Market:

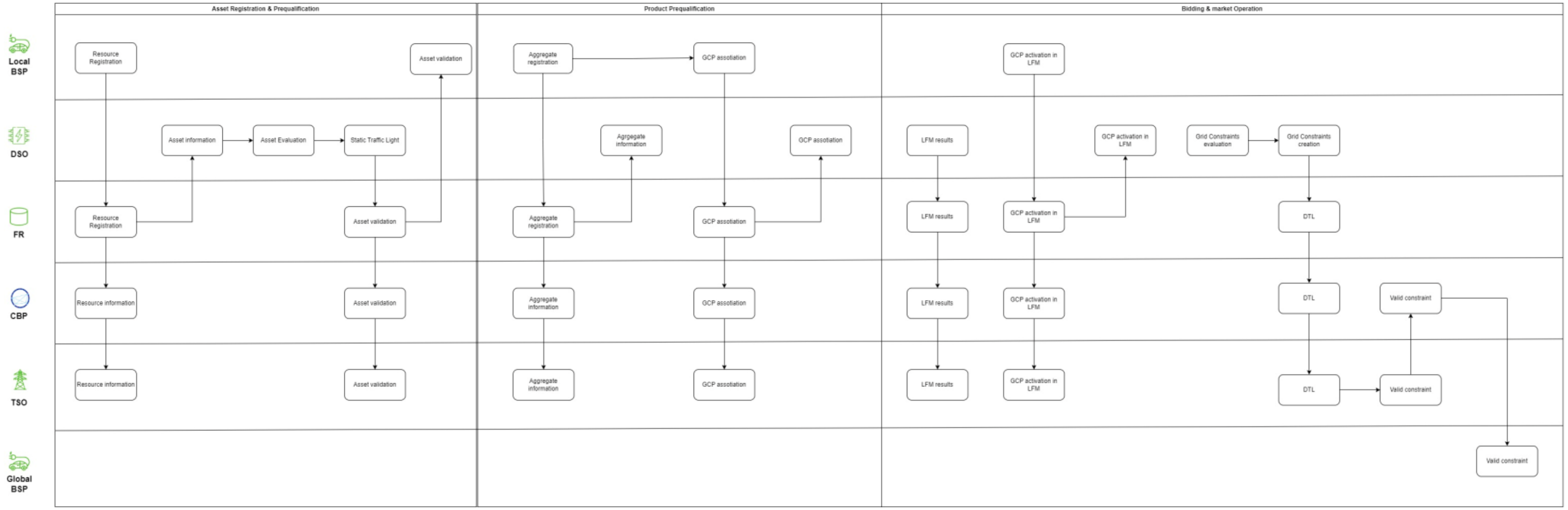

Figure 35 - Journey LFM

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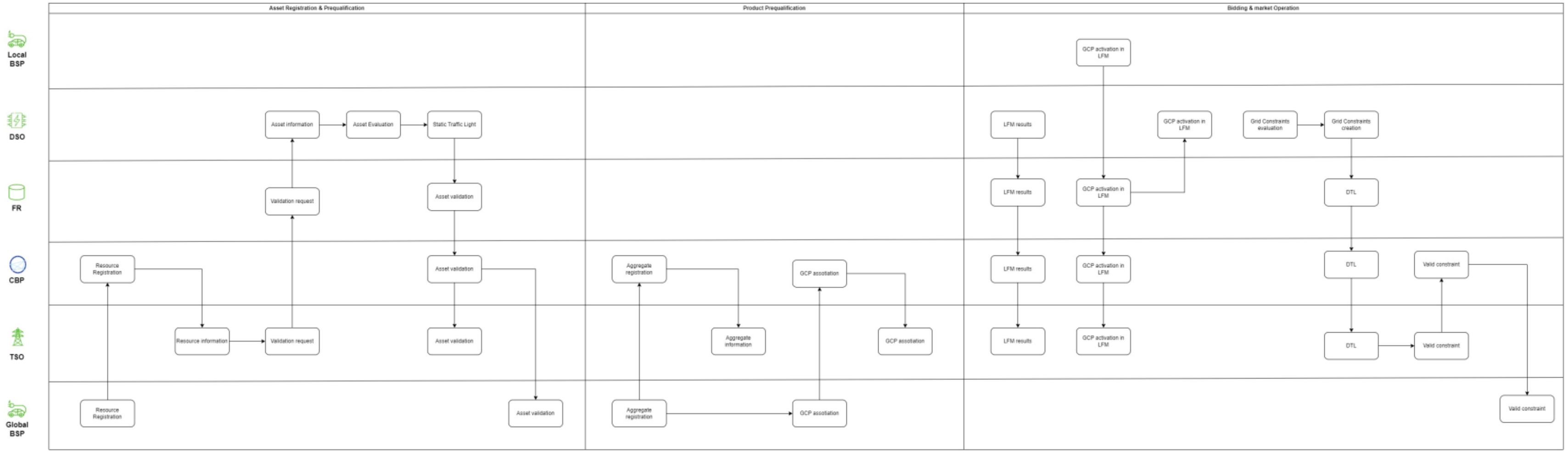

Figure 36 - Journey GFM

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10.2. Functionalities

In the scope of the BeFlexible project, the CBP platform and the FR will use the following functionalities in order to facilitate TSO, DSOs and BSPs activities and coordination on the LFM and GFM:

Table 11 - Phases and services of the flexibility procurement coordination between CBP e FR

PHASE	SERVICE	METHOD	SENDER	RECEIVER	NOTE
Asset Registration & prequalification	Register Flex Resource (LFM)	POST	FR	CBP	Updates will be managed with the PATCH method
	Register Flex Resource (GFM)	POST	BSP	CBP	Updates will be managed with the PATCH method
	Complete Resource Information	PATCH	CBP	FR	
	Static Traffic Light	PATCH	FR	CBP	
Product prequalification	Register Resource Group (LFM)	POST	FR	CBP	Updates will be managed with the PATCH method
	Register Resource Group (GFM)	POST	BSP	CBP	Updates will be managed with the PATCH method
	Register Resource in Resource Group (LFM)	POST	FR	CBP	
	Register Resource in Resource Group (GFM)	POST	BSP	CBP	
Bidding & market operation	Communicate Local Market Results	POST	FR	CBP	
	GCP activated in LFM	POST	FR	CBP	
	Dynamic Traffic Light	POST	FR	CBP	Updates will be managed with the PATCH method

The structure and use of the interfaces related to the above-mentioned functionalities are described in the following paragraphs. The interfaces are made available with authenticated REST-type APIs; the format of the information exchange is JSON.

10.3. Asset Registration & Prequalification

10.3.1. Register Flex Resource

Table 12 - Register flex resources overview

NAME	Register Flex Resource

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DESCRIPTION	Service used by the BSP to register its assets on one of the reference markets: Local Flexibility Market (with FR as entry point) or Global Flexibility Market (with CBP as entry point)
METHOD	POST
SWAGGER	*tbd*

The following table describes the interface fields:

Table 13 - Register flex rosurces interface fields

INFORMATION	DESCRIPTION	FIELD TYPE	POSSIBLE VALUES	CARDINALITY	NOTES
BSP Code	Identification Code of the BSP represented by Partita IVA	String	BSP Partita IVA	Mandatory	Maximum 50 car.
Grid Connection Point ID	Code identifying the Grid Connection Point	String	GCP Code	Mandatory	
Grid Connection Point Type	Type of GCP	String	• Consumption • Generation • Mixed	Mandatory	
Local Market Type	Define the Local type of market for the flexibility resource.	Boolean	• Yes • No	Mandatory	
Global Market Type	Define the Global type of market for the flexibility resource.	Boolean	• Yes • No	Mandatory	
Location	ISTAT code associated to the resource	String	ISTAT code	Mandatory	
Generation Unit ID	Code of the Generation Unit.	String		Mandatory if Global Market Type is yes	
Contracted Power	The power level made available by the resource for the power supply	Number		Mandatory	

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Maximum Flex Up	Flexible upward power	Number		Mandatory	
Minimum Flex Down	Flexible downward power	Number		Mandatory	
Grid Voltage Level	The grid voltage level communicated by the BSP.	String	• AAT 380 kV • AAT 220 kV • AT 150 kV • AT 120-132 kV • AT 40-90 kV • MT 23-39 kV • MT 17-22 kV • MT 11-16 kV • MT 1-10 kV • BT	Mandatory	
Flexibility Asset Technology Type	Technology that enables the resource to provide flexible power.	String	• Accumulo elettrochimico • Eolico • Solare • Geotermico • Prelievi utenza BT • Prelievi utenza AAT/AT/MT • Prelievi stazioni di ricarica per EV • Altro	Mandatory	
DSO EIC Code	EIC Code for the relevant DSO on whose network the resource belongs	String		Mandatory	Maximum 50 car.

10.3.2. Static Traffic Light

Table 14 - Static traffic light overview

NAME	Static Traffic Light
DESCRIPTION	Service used by the RF to share the static validation of the resource performed by the relevant DSO
METHOD	PATCH

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SWAGGER	*tbd*

The following table describes the interface fields:

Table 15 - Static traffic light interface fields

INFORMATION	DESCRIPTION	FIELD TYPE	POSSIBLE VALUES	CARDINALITY	NOTES
Grid Connection Point ID	Code identifying the Grid Connection Point	String	GCP code	Mandatory	
BSP ID Code	Identification Code of the BSP	String	P. IVA BSP	Mandatory	Maximum 50 car.
Distribution Location ID	DSO Perimeter ID representing the individual node/element/aggregate of nodes in the distribution network to which the distributed flexibility resource refers.	String		Mandatory	
Distribution Location Type	Type of DSO Perimeter	String	• _CS in case of Secondary Substation • _AG in case of aggregates of DSO elements • _LN in case of LV line	Mandatory	
Static Traffic Light Flag Up	A predefined colour codification for a Go, Go-if, No-Go system: • Green when there is no limitation on the use of the resource • Yellow for limitations on the use of the resource or for reporting inconsistencies in the asset details or technical data declared by the BSP • Red in case of invalid resource	String	• green • yellow • red	Mandatory	
Static Traffic Light Flag Down	A predefined colour codification for a Go, Go-if, No-Go system: • Green when there is no limitation on the use of	String	• green • yellow • red	Mandatory	

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	the resource • Yellow for limitations on the use of the resource or for reporting inconsistencies in the asset details or technical data declared by the BSP • Red in case of invalid resource				
DSO Validated Upward Power	The amount of modulating power the DSO can accept the GCP for, in the upward direction	Number		Mandatory	
DSO Validated Downward Power	The amount of modulating power the DSO can accept the GCP for, in the downward direction	Number		Mandatory	
Motivation	The motivation related to the choice of traffic light colour.	String	In the case of a yellow traffic light, the motivation is useful to indicate any inconsistencies in the personal or technical data declared by the BSP. In the case of a red traffic light, the motivation is useful to clarify the reason why the resource cannot participate in the market	Mandatory	Maximum 4000 characters
Measurement treatment	Measurement treatment for the resource	String	•hourly •non_hourly_measurements •hourly_measurements_na	Mandatory	If the field value is "hourly measurements na" both STL flag should be red

10.3.3. Sequence Diagram for Asset Registration and Prequalification process

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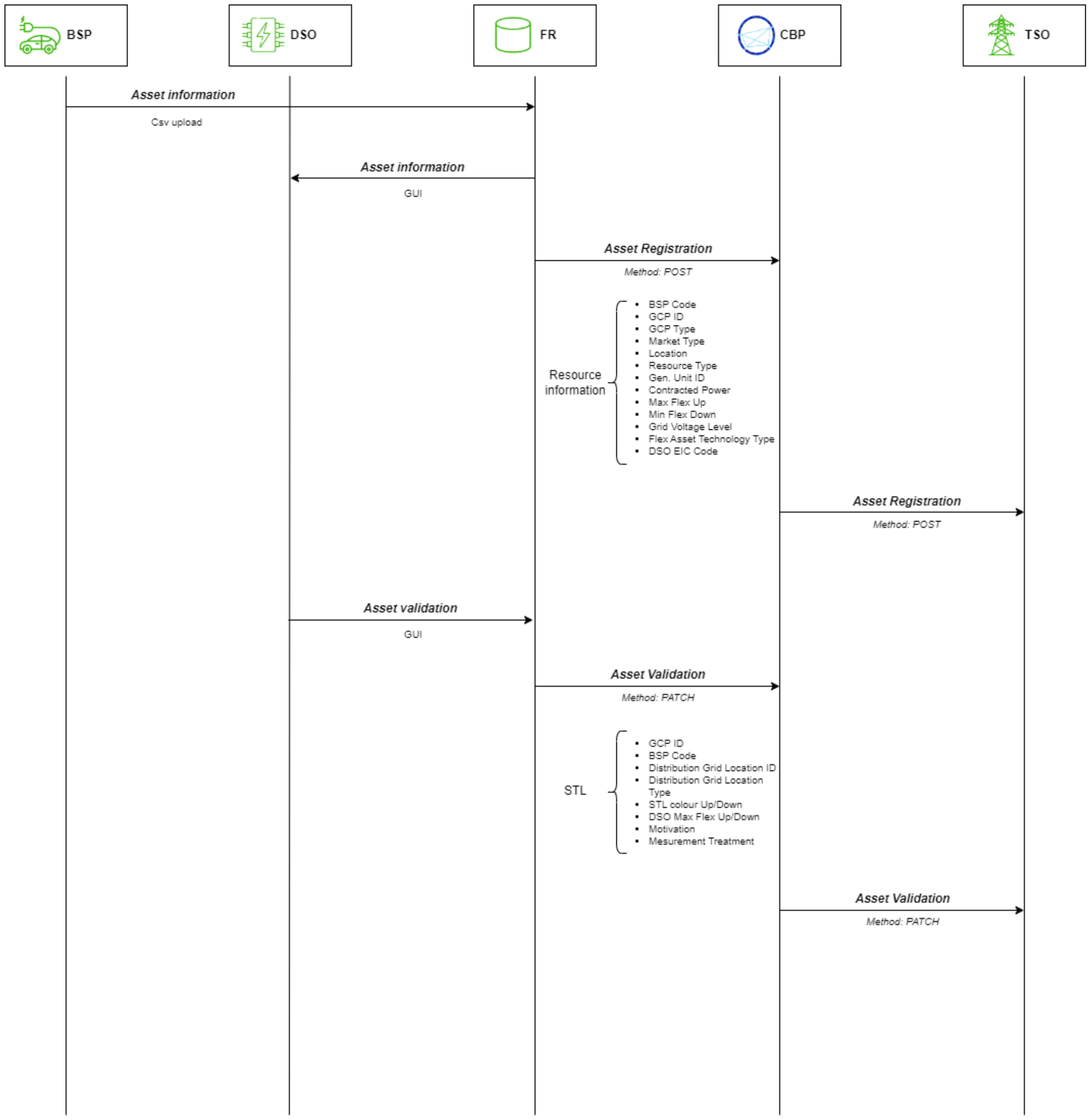

Figure 37 - Asset registration and prequalification on LFM

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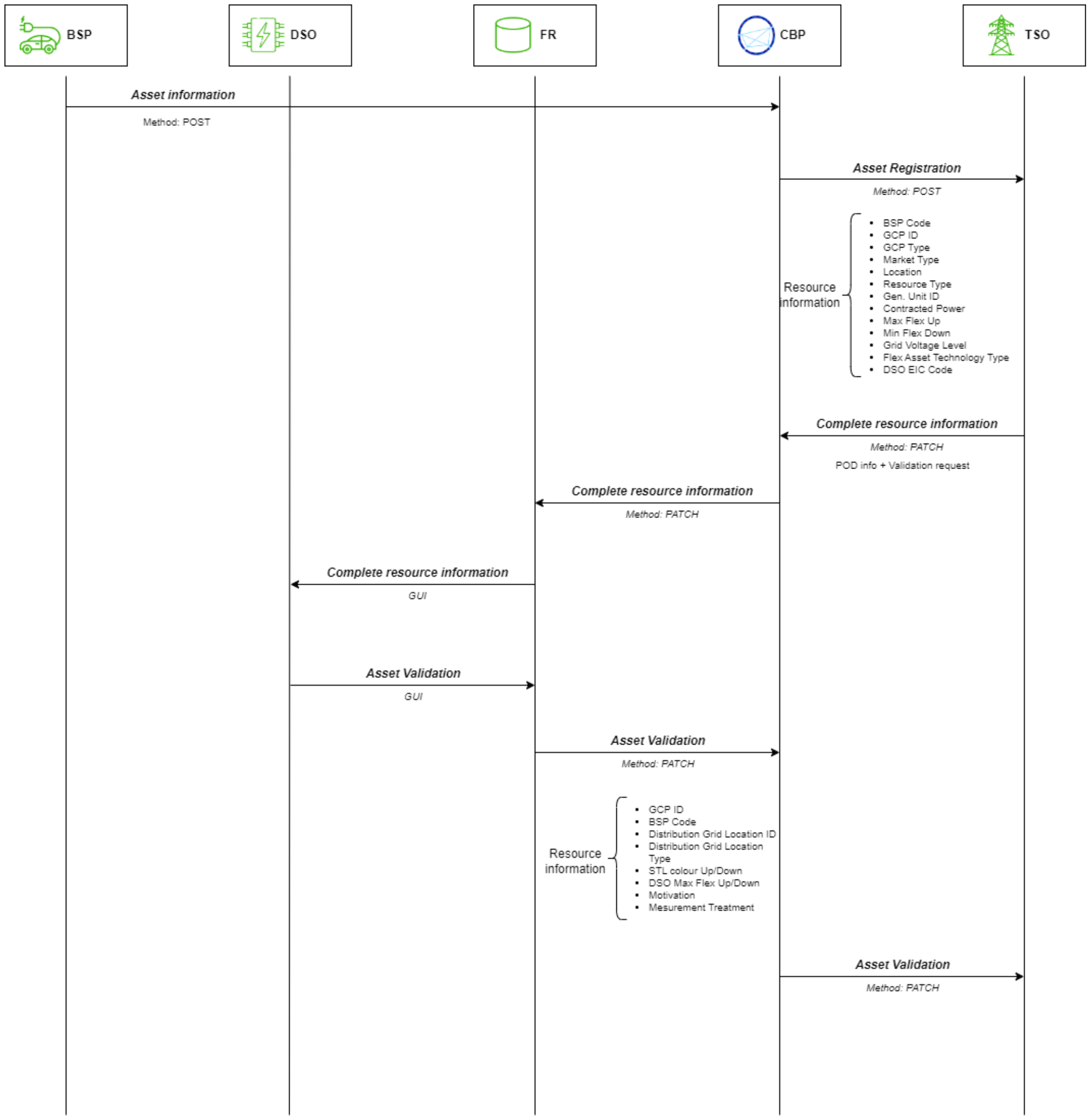

Figure 38 - Asset registration and prequalification on GFM

10.4. Product Prequalification

10.4.1. Register Resource Group

Table 16 - Register resource group overview

NAME	Register Resource Group
DESCRIPTION	Service used by the BSP to record the information of a global or local aggregate depending on the platform used (FR for LA, CBP for GA).

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METHOD	POST
SWAGGER	*tbd*

Table 17 - Register resource group interface fields

INFORMATION	DESCRIPTION	FIELD TYPE	POSSIBLE VALUES	CARDINALITY	NOTES
BSP Code	Identification Code of the BSP	String	P. IVA BSP	Mandatory	Maximum 50 car.
TSO/DSO EIC Code	TSO/DSO EIC Code that is receiving the aggregate information	String		Mandatory	Maximum 50 car.
Resource Group Market Type	Market Type of the aggregate	String	•Local Market Type •Global Market type	Mandatory	
Resource Group Name	Name of the aggregate	String	For aggregates registered on the LFM, the name must begin with LA followed by a sequential numbering. For aggregates registered on the GFM, the name must begin with GA followed by a sequential numbering.	Mandatory	Maximum 50 car.
Aggregation perimeter	Aggregation perimeter	String	If GA: • NORD OVEST TO • NORD OVEST GE • NORD OVEST BS • NORD OVEST MI • NORD EST VE • NORD EST BO • DORSALE TIRRENICA RM • DORSALE TIRRENICA NA • DORSALE TIRRENICA FI • DORSALE TIRRENICA CZ • DORSALE ADRIATICA PE	Mandatory	

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			• DORSALE ADRIATICA AN • DORSALE ADRIATICA BA • DORSALE ADRIATICA TA • DORSALE UMBRA PG • DORSALE UMBRA TR • SICILIA • SARDEGNA If LA: TBD		
Minimum qualified power	Minimum qualified power of the aggregate expressed in MW	Number		Mandatory	
Maximum qualified power	Maximum qualified power of the aggregate expressed in MW	Number		Mandatory	
Services for Global Market	Services for GFM	String	• A = Riserva terziaria sostituzione salire • B = Riserva terziaria sostituzione scendere • C = Riserva terziaria rotante salire • D = Riserva terziaria rotante scendere • E = Risoluzione congestioni salire • F = Risoluzione congestioni scendere • G = Bilanciamento salire • H = Bilanciamento scendere • I = Risoluzione congestioni locali It is possible communicate more than one value.	Mondatory if Resource Group Market Type is "Global Market Type"	
timePower	Tempo di attivazione servizio potenza attiva.	Number		Mandatory if Resource Group Market Type is "Local Market Type"	
maxTimePower	Tempo massimo di fornitura servizio di potenza attiva.	Number		Mandatory if Resource Group Market Type is	

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				"Local Market Type"	
minTimePower	Tempo minimo di fornitura servizio di potenza attiva.	Number		Mandatory if Resource Group Market Type is "Local Market Type"	
startTimePower	Tempo di rampa iniziale servizio di potenza attiva.	Number		Mandatory if Resource Group Market Type is "Local Market Type"	
endTimePower	Tempo di rampa finale servizio di potenza attiva	Number		Mandatory if Resource Group Market Type is "Local Market Type"	
recoveryTimePower	Tempo di recupero servizio di potenza attiva.	Number		Mandatory if Resource Group Market Type is "Local Market Type"	

10.4.2. Register Resource in Resource Group

Table 18 - Register resource in resource group overview

NAME	Register Resource in resource Group
DESCRIPTION	Service used by the BSP to associate Grid Connection Point to a global or local aggregate.
METHOD	POST
SWAGGER	*tbd*

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Table 19 - Register resource in resource group interface fields

INFORMATION	DESCRIPTION	FIELD TYPE	POSSIBLE VALUES	CARDINALITY	NOTES
BSP Code	Identification Code of the BSP	String	P. IVA BSP	Mandatory	Maximum 50 car.
TSO/DSO EIC Code	TSO/DSO EIC Code that is receiving the aggregate information	String		Mandatory	Maximum 50 car.
GCP ID	The CBP blockchain ID for the GCP to associate to the aggregate	String		Mandatory	
Resource Group Name	Name of the aggregate	String	For aggregates registered on the LFM, the name must begin with LA followed by a sequential numbering. For aggregates registered on the GFM, the name must begin with GA followed by a sequential numbering.	Mandatory	Maximum 50 car.
Resource Group ID	The CBP blockchain ID for the aggregate to which the GCP is associated	String		Optional	Maximum 50 car.

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10.4.3. Sequence Diagram for Product Prequalification process

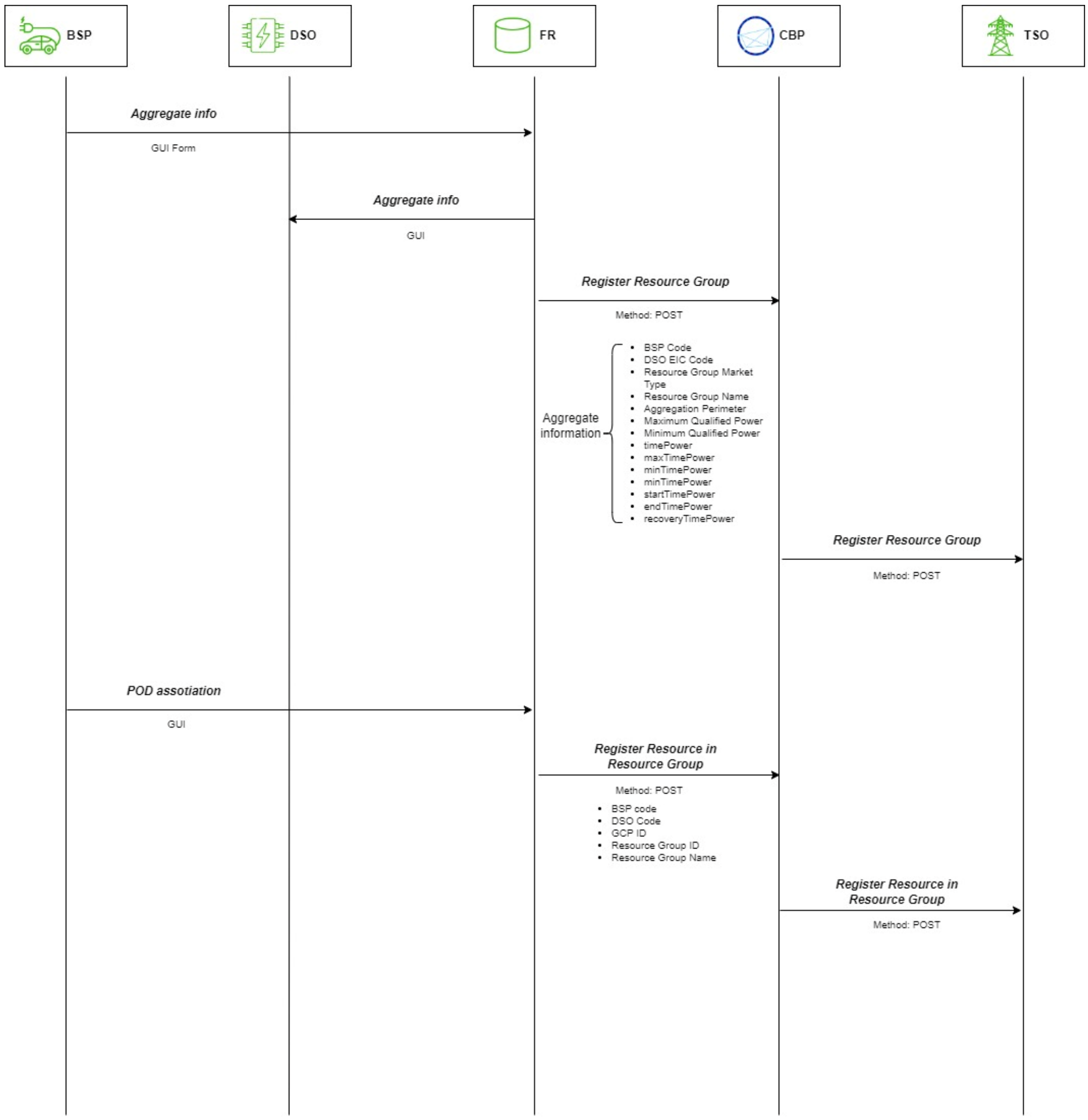

Figure 39 - Product prequalification on LFM

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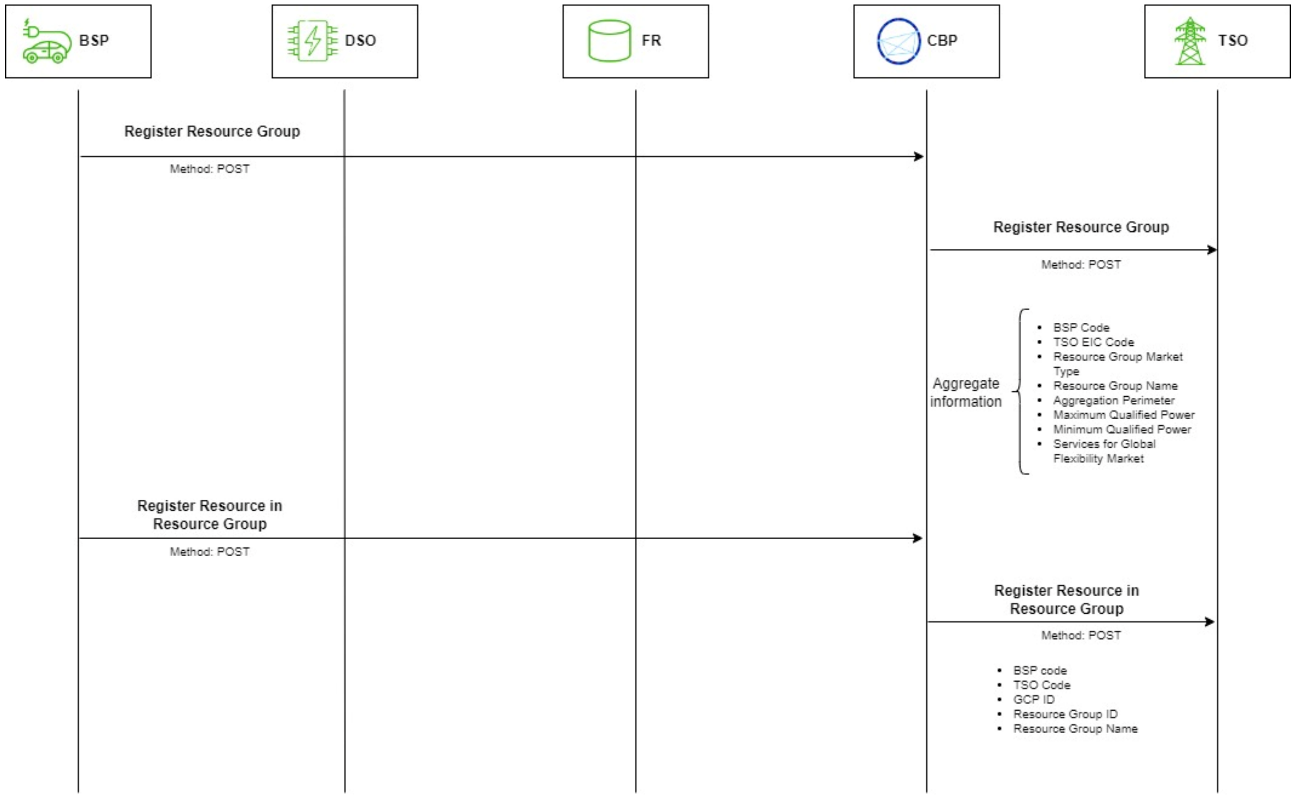

Figure 40 - Product prequalification on GFM

10.4.4. Bidding and market operations

10.4.5. Communicate Local Market results

Table 20 - Communicate local market results overview

NAME	Communicate Local Market Results
DESCRIPTION	Service used by the DSO to communicate, through the FR, the results for LFM
METHOD	POST
SWAGGER	*tbd*

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Table 21 - Communicate local market results interface fields

INFORMATION	DESCRIPTION	FIELD TYPE	POSSIBLE VALUES	CARDINALITY	NOTES
BSP Code	Identification Code of the BSP.	String		Mandatory	Maximum 50 car.
Resource Group Name	Name of the aggregate	String	For aggregates registered on the LFM, the name must begin with LA followed by a sequential numbering. For aggregates registered on the GFM, the name must begin with GA followed by a sequential numbering.	Mandatory	Maximum 50 car.
Resource Group ID	The Identification code of the Resource Group activated by the DSO in LFM.	String		Mandatory	Maximum 50 car.
Activation Request ID	ID for the flexibility request of the DSO to witch the aggregate is selected for	String		Mandatory	
Direction	Indicates the direction of power (up, down)	List	• UP • DOWN	Mandatory	
Delivery Time Interval	Delivery period for the resource group to be activated by DSO for providing the service in LFM				
start date		Number		Mandatory	
end date		Number		Mandatory	
Total activated quantity (Q)	Represents the total quantity activated in the LFM by the DSO	Number		Mandatory	

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10.4.6. GCPs activated in Local Flexibility Market

Table 22 - GCPs activated in LFM overview

NAME	GCPs activated in LFM
DESCRIPTION	Service used by the BSP to communicate GCPs activated in LFM
METHOD	POST
SWAGGER	*tbd*

Table 23 - GCPs activated in LFM interface fields

INFORMATION	DESCRIPTION	FIELD TYPE	POSSIBLE VALUES	CARDINALITY	NOTES
BSP Code	Identification Code of the BSP.	String		Mandatory	Maximum 50 car.
Activation Request ID	ID for the flexibility request of the DSO to witch the aggregate is selected for	String		Mandatory	
Resource Group Name	Name of the aggregate	String	For aggregates registered on the LFM, the name must begin with LA followed by a sequential numbering. For aggregates registered on the GFM, the name must begin with GA followed by a sequential numbering.	Mandatory	Maximum 50 car.
Resource Group ID	The Identification code of the Resource Group activated by the DSO in LFM.	String		Optional	Maximum 50 car.
GCP ID	ID of the GCP part of the Resource Group and selected for the activation in LFM	Array		Mandatory	

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10.4.7. Dynamic Validation (Dynamic Traffic Light)

Table 24 - Dynamic traffic light overview

NAME	Dynamic Traffic Light
DESCRIPTION	Service used by the DSO to communicate, through the FR, to communicate grid constraints to Terna
METHOD	POST
SWAGGER	*tbd*

Table 25 - Dynamic traffic light interface fields

INFORMATION	DESCRIPTION	FIELD TYPE	POSSIBLE VALUES	CARDINALITY	NOTES
Distribution Grid Location ID	DSO Perimeter ID	String		Mandatory	Maximum 50 car.
DTL Validity Interval	Validity interval for the constraint communicated by the DSO	Number		Mandatory	
Start date		Number		Mandatory	
End Date		Number		Mandatory	
Resolution	Time resolution for the constraints communicated.	String	• Hourly resolution (PT60M) • Quarter-hourly (PT15M)	Mandatory	
Direction	The direction of power upward/downward	List	• Up (A01)	Mandatory	

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			• Down (A02)		
DTL colour codification	Color codification expressed for each hourly or quarter-hourly delivery period of the delivery day for both the "downward" and "upward" directions: • Green when no restriction is needed on the use of flexibility resources • Yellow if restrictions on the use of flexibility resources are needed. Red if the use of flexibility resources is not possible for the existence of criticalities	List		Mandatory	
DTL Capability	The actual value of the constraint associated to the DTL Colour: • Green DTL automatically implies a capability equal to a generic high enough value (9999) $Green\ DTL \Rightarrow Cap = +\infty = 9999$ • Yellow DTL $\text{Yellow DTL} \Longrightarrow \text{Cap} \neq 0 \begin{cases} P_{Up} \Leftrightarrow Cap > 0 \\ P_{Down} \Leftrightarrow Cap < 0 \end{cases}$ • Red DTL implies a capability value equal to “0” $Red\ DTL \Rightarrow Cap = 0$	String		Mandatory	
Contraint motivation	The reason for the constraint is expressed	String		Mandatory if ref and/or yellow	

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10.4.8. Sequence Diagram for bidding & market operation

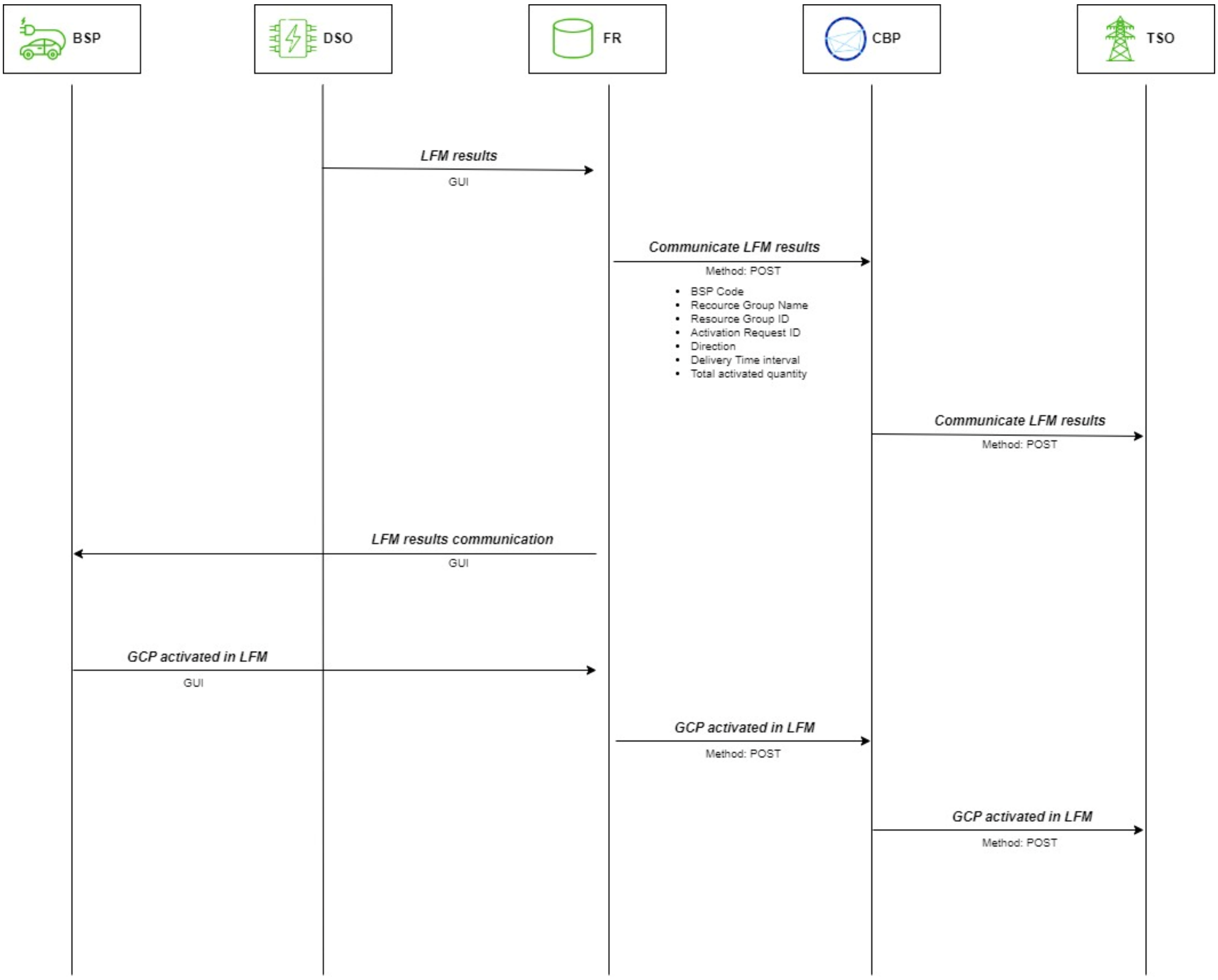

Figure 41 - LFM result communication and GCP activation communication

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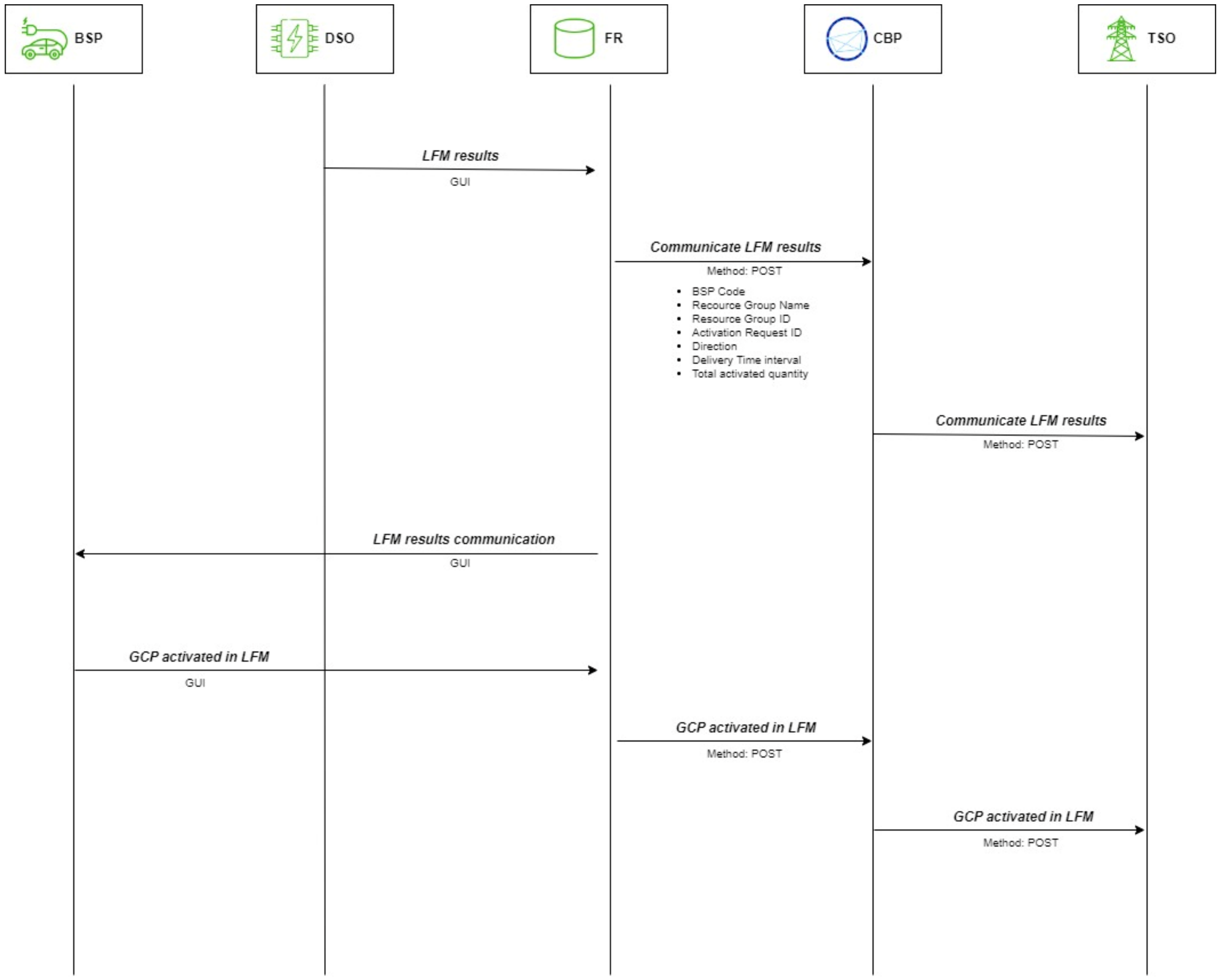

Figure 42 - Dynamic traffic light communication

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