D4.1

DEMO 1 Methodological Report

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Table of contents

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

List of figures

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List of Tables

List of abbreviations

API	Application Programming Interface
CM	Congestion Management
CBP	Crowd Balancing Platform
aFRR	Automatic Frequency Restoration Reserve
mFRR	Manual Frequency Restoration Reserve
STL	Static Traffic Light
DTL	Dynamic Traffic Light
ASM	Ancillary Service Market
MSD	Mercato dei Servizi di Dispacciamento (Ancillary Services Market)

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LFP	Local Flexibility Platform
IT	Information Technology
MOL	Merit Order List
CS	Coordination Scheme
DEMO	Demonstrator
DER	Distributed Energy Resource
SP	Service Provider
BSP	Balancing Service Provider
PGUI	Power Grid User Interface
POD	Point of Delivery
UVAM	Virtually Aggregated Mixed Unit
WP	Work Package

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1. Executive Summary

This deliverable lies under the scope of Work Package 4 – "South-Mid EU demo – fast-track" and is a result of Task 4.1 – "Preparatory demo framework, pilots' validation plan and assessment methodology".
The task aims to provide a conceptual framework for efficient management and operation of the activities within the fast-track DEMO 1, which results will be used for the other two Demos of the BeFlexible project.

In particular, the activity was focused on designing the high-level principles for the *coordination* between TSO and DSOs for the procurement of local and global congestion management and voltage control services (hereby referred as "flexibility services") within their own procurements frameworks: the first phase of the activity is dedicated to a comprehensive review of relevant EU projects that concerns this theme and considers them as a starting point for the definition of the coordination mechanism. Besides, ongoing pilot projects developed in Italy are described in order to illustrate the regulatory background upon which the coordination mechanism is developed:

- *Traffic light mechanism pilot project,* led by Terna, aiming at introducing in the regulation and grid code an evolution of the TSO-DSO coordination mechanisms for the management of distributed flexibility (namely the one provided by resources connected to distribution grids) to the global ancillary service market;
- *RomeFlex*, managed by Areti, aiming at the creation of a complete Local Flexibility Market to serve all the users in the City of Rome;
- *EDGE*, managed by E-distribuzione, aiming at testing planning, procurement and operation of flexibility services for grid constraints management. It involves portion of the distribution networks of Cuneo, Benevento, Foggia, and Venice.

The DEMO operates as a layer for the coordination, integration and improvement of the national pilot projects but does not replace them. All the experimentation specific to the respective national pilots is carried out within themselves outside of this DEMO. National pilots are the main container of each experimentation, the DEMO can integrate and test only those processes which are not foreseen in the national pilots themselves.

After the above review, T4.1 deals with the mapping and characterization of testing scenarios, Business Use Cases (BUCs), and System Use Cases (SUCs) in the different pilot areas, which differ in the type of territory served (urban, rural), the energy domain, and the flexibility resources that could be involved: Pilot 1.1 - Rome; Pilot 1.2 - Foggia, Benevento; Pilot 1.3 - Cuneo.

In the RomeFlex pilot, which comprises the entire network of Rome, the flexibility services can be provided by any asset regardless of technology, it will be mainly delivered by programmable storage, controllable loads (appliances, water heaters, heat pumps...), cogeneration plant, V1G charging stations. Furthermore, the water infrastructure will be involved in the national pilot. The perimeter of interest of the EDGE pilot project, adopted in Beflexible, is identified in portions of the networks supplying the provinces of Foggia and

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Benevento (pilot 1.2) and Cuneo (pilot 1.3). Overall, the selected areas include medium and small urban areas, agricultural, industrial and mountain areas.

Firstly, a brief description of the BUCs of interest to DEMO 1 is given, then each association with the 3 Italian pilots is organized schematically and clearly in a table form: BUCs with relative SUCs preliminary selected in the specific pilots of the Italian Demo, correlating them to the services identified in the GA and selected for demonstration. Since DEMO 1 has a conceptual and practical link with the above mentioned National projects on the traffic light mechanism and on local flexibility services, that will be fully deployed starting from 2024, the selected BUCs and SUCs, focused on the coordination between System Operators (SOs), should be refined further in a following stage. Therefore, it's not possible to identify clearly what processes will be implemented in the real field and which processes will be simulated. Finally, at the delivery date of this document (M14, October 2023) the discussions are still ongoing in the relevant Tasks and some adjustments could be further applied.

Then, an in-depth analysis is carried out on the coordinated process of resource procurement: the model has been designed starting from the so-called *multi-level market model* given in the CoordiNet project. It considers two separate buyers of flexibility (TSO and DSO), and different market-based frameworks to procure flexibility depending on the service to be procured. Long-term contracts and short-term markets are the alternatives considered for the procurement of flexibility services. The description of the process was then divided into steps: registration; pre-qualification; market and planning phase; and real time activation and settlement.

In order to simplify and unify registration procedures for Service Providers (SPs) in the Italian DEMO, the concept for a common registration mechanism is established leveraging the Crowd Balancing Platform (CBP) and its data registry functionalities (as built in its Flexibility Register module), which contains all the functionalities needed to perform the registration and prequalification activities. After the SP has registered the resources through the CBP's Flexibility Register functionalities, the information is forwarded to the respective SO (and their data registry systems) entitled to perform the ex-ante validation to ensure that the resource flexibility can be actually delivered, based on technical information held by the SO itself.

The prequalification procedure is used to verify that SPs can indeed provide the services as requested by grid code or other regulation by means of the registered resources or aggregate of resources. To coordinate TSO and DSO prequalification process and to simplify and streamline the procedure from the point of view of the SP, the principle of a *Table of Equivalences (ToE)* is defined. The *table of equivalences* is a tool able to cross-reference technical requirements giving the possibility of considering an aggregate automatically prequalified for different products with respect to the one investigated during technical tests. Therefore, thanks to this tool, a single prequalification process could be conducted to qualify an aggregate in providing more than one service.

For Local Flexibility Services (LFS), the short-term planning process, as first hypothesis for DEMO purpose, is supposed to be triggered as a parallel process to the usual planning occurring in the ancillary service market

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(ASM, called MSD in Italy). In the Italian DEMO, the timing scheme is organized according to the actual structure of MSD. Each session of the LFS planning closes before the TSO planning session for the same delivery period. The definition of this planning schedule helps in defining a preliminary hypothesis of market coordination which is based on the *principle of mutual unavailability* of shared flexibility assets, thus those assets which are enabled to procure both global and local flexibility services. The principle of mutual unavailability, as by this first hypothesis, consists of the exclusion from the following market sessions of the flexibility which has already been selected in previous sessions. Thanks to the definition of the mutual unavailability principle and the use of sequential markets, settlement between TSO and DSO can be processed separately given that each resource (represented by its grid connection point) can offer services for one system operator only in the same delivery period.

With respect to the above framework, the Italian fast-track demo uses different platforms and tools which continuously communicate with each other. The Crowd Balancing Platform (CBP) is the main technological tool entitled to manage the distributed data exchanges taking place within the coordination mechanism. The Flexibility Register (FR) is the functionality representing a repository system where all data related to flexible Points of Delivery (PODs) are stored and made available to demo platforms and stakeholders. The DSO Technical Platform allows to forecast grid congestions and voltage violations, to define flexibility requests to solve the forecasted issues, and to verify that all market outcomes, including the ones related to TSO requests, are compliant with grid constraints. Finally, the Blockchain Access Layer connects the device at flexible resource's premise to the FR ensuring, through timestamping features, the immutability of data along the whole path.

The expected benefits deriving from the exploitation of flexibility from distributed resources were then summarized, with respect to the different stakeholders of the energy system: consumers/prosumers, DSOs, TSOs, Governments and Regulators.

The demonstration plan was outlined, considering the activities related to the objective of the Project: engagement of flexibility resources, fine tuning of services and platforms, operation and KPIs calculation. As mentioned before, with respect to the *coordination* the interactions between actors and systems will be simulated.

Finally, a list of Key Performance Indicators (KPIs) was defined, in coordination with the ongoing activities in Task T3.1, in order to assess two different macro-goals: analyze the exploitation of flexibility resources in planning and operational activities, with particular attention on the impact of TSO-DSO cooperation on them. As mentioned before, this activity will continue after the release of this deliverable, also according to the evolution of WP1 tasks – therefore, the possibility to update definitions or calculation methodologies is left to DEMO developers.

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2. Introduction

BeFlexible project aims at fostering the exploitation of flexibility spreading knowledge among prosumers and encouraging them to participate is the provision of flexibility. The project focuses on four macro-areas (Markets and Regulation, Services Ecosystem, Platforms & Architecture and Customer engagement), each relevant in order to reach the final objective which include to validate possible design alternatives analysing their profitability, scalability and replicability. In order to: 1) demonstrate flexibility potential; 2) assess the impact of services, platforms and architecture; 3) evaluate consumer engagement strategies and foster the market uptake, 11 pilots will be deployed in 4 different countries, testing the solutions in different regulatory environments and in alignment with national plans. The present deliverable is conceived as an input for planning the demonstrating activities (DEMO) in three different involved sites (each of them involved in a Pilot): *Roma*, *Foggia & Benevento and Cuneo*. The DEMO aims at implementing the reference architecture for the procurement of global and local flexibility services in a coordinated process. On the basis of the analysis performed in previous packages of the BeFlexibile project, in particular WP1-Task 1.4 and WP3-Task 3.1 where respectively business and system use cases, services and tools have been defined, and taking into account solutions of previous EU/National projects; here, the guidelines and concepts for the implementation of the national pilot projects are introduced and described.

In this document, the different steps of the markets access, operation and coordination are defined. Starting from the definition of a coordinated and common prequalification procedure, then a possible coordination mechanism for the planning phase of global and local markets is defined. Finally, also the activation and validation steps to be tested in the DEMO are described. The development of such processes follows the national pilot projects proposed by the three stakeholders, thus compliant with the national regulatory framework. In this context, the DEMO operates as a layer for the coordination, integration and improvement of the national pilot projects but does not replace them. Therefore, considering that all the experimentation specific to the respective national pilots is carried out within themselves outside of this DEMO, the DEMO will focus on reporting what has been tested within the national pilots in the sites also identified for the Italian DEMO and implementing all those additional processes designed for BeFlexible aimed at TSO-DSO coordination for the procurement of global and local flexibility services.

DEMO 1 acts as a *fast-track* demo with respect to the other DEMOs, and its conclusions and lessons learned will be used for the other two demos of the Project. Finally, the aim of the task here described is to provide a consolidated conceptual framework for an efficient management and operation of the pilots within this fast-track demo, including:

- the agreed TSO/DSO/market actors/end user's coordination schemes and market designs to be applied,
- the agreed integration model for all TSO/DSO/market actors/third parties' platforms and tools, and
- the preliminary list of services, according to ongoing WP3 activities.

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To ensure full coverage and correct assessment of the results, T4.1 address the following topics:

- Chapter 3: it represents a literature review of the already analysed coordination schemes and market designs from previous EU projects. Some concepts are introduced in terms of advantages and disadvantages of the different schemes to give and overview of preliminary understandings. Furthermore, a detailed analysis of the current Italian Pilots is given so to introduce the present framework where coordination schemes have to be introduced.
- Chapter 4: From the outcomes of WP1 and WP3, here only *business use cases* (BUC) and *system use cases* (SUC) related to the DEMO are recalled. Each of them is associated with the pilots entitled to test them.
- Chapter 5: Technical specifications of the pilot installations; network aspects including characteristics of flexibility assets involved.
- Chapter 6: The mechanism for the procurement of flexibility resources in a coordinate framework is described in detail. Chronological scheduling and information exchange between TSO and DSO are in depth analysed.
- Chapter 7: It contains a description of the different tools and their functionalities used to develop the mechanism described in Chapter 6.
- Chapter 8: Here the expected benefits to different stakeholders are illustrated contextualizing them in the European regulatory framework and supposing further additional *surplus* brought by the development of such mechanism. Furthermore, the effectiveness of platform integration and services offered is analysed together with the impact on transmission and distribution grid.
- Chapter 9: Finally, the scope and goals of the projects are described and relevant KPIs to be used to assess the quality of the solution from an operative & technical perspective are given.

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3. Summary of the coordination schemes and market designs

In the following, the schemes relevant for the scope of this WP are summarized. Other European and national projects were analysed but considered not significant for their further exploitation, because they were basically similar to the previous ones, or because they were developed in frameworks with goals different from the BeFlexible's objectives. This review is considered as a starting point for the development of a coordination scheme between TSO and DSO. In detail, ongoing pilot projects developed in Italy are described in Section 3.5 in order to illustrate the regulatory background upon which the coordination mechanism is developed.

3.1. SmartNet

The SmartNet project [1] aimed to provide optimised instruments and modalities to improve the coordination between the grid operators at national and local level (respectively the TSOs and DSOs) and the exchange of information for monitoring and for the acquisition of ancillary services (reserve and balancing, voltage balancing control, congestion management) from subjects located in the distribution segment (flexible load and distributed generation).

SmartNet compared different architectures for optimized interaction between TSOs and DSOs in managing the purchase of ancillary services (reserve and balancing, voltage regulation, congestion management) from subjects located in the distribution segment. An *ad hoc* simulation platform was built over three layers (physical network, market and ICT) in order to simulate three national cases (Italy, Denmark, Spain), also demonstrated in physical pilots. **Figure 1** summarizes the 5 Coordination Schemes (CS) developed by the project and a summary of advantages and disadvantages in provided in Figure 2. To give a general overview of the different schemes, they can be described as follow:

- CS A – *Centralized ancillary services market model*:
  - One common ancillary services market managed by the TSO
  - Separate DSO process for checking distribution constraints (e.g. prequalification)

- CS B – *Local ancillary services market model*:
  - Separate local market managed by the DSO for local issues
  - Transfer remaining flexibility to TSO ancillary services market level

- CS C – *Shared balancing responsibility model*:
  - Ancillary services market for transmission resources managed by TSO
  - Local market for distribution resources managed by DSO
  - Agreed pre-defined TSO-DSO scheduled profile (net exchange at the Primary Substation)

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- CS D – *Common TSO-DSO ancillary services market model*:
  - Common flexibility market managed jointly by TSO and DSO
  - Variants: One optimization with all grid constraints, Two optimizations: distribution and transmission constraints
- CS E – *Integrated flexibility market model*:
  - Common flexibility market managed by an independent and neutral market operator
  - No priority for TSO, DSO or commercial market player.

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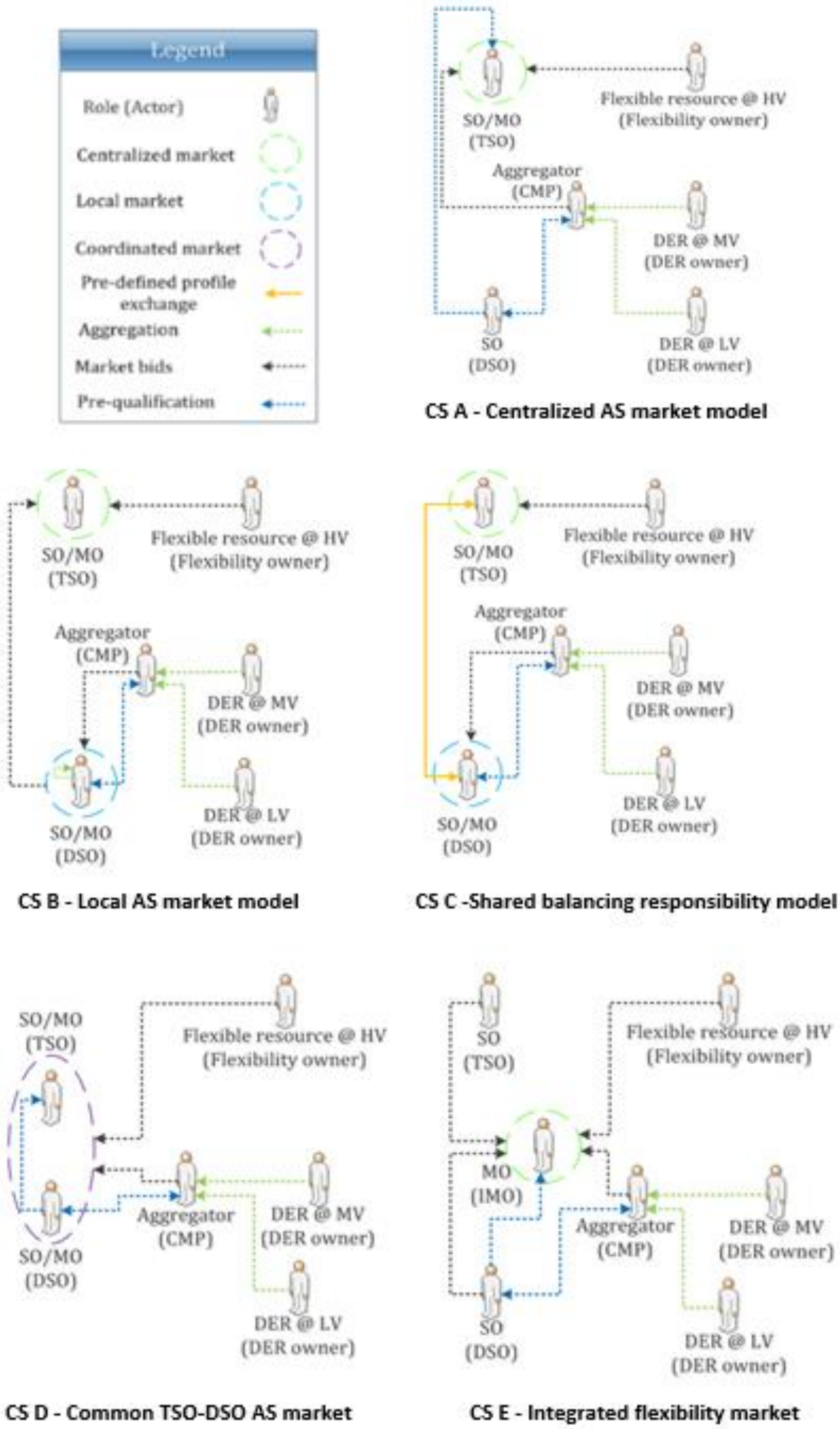

Figure 1 – Coordination Schemes of project SmartNet [1].

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Domain	Performance criteria	Coordination scheme				
		Centralized AS market model	Local AS market model	Shared balancing responsibility model	Common TSO-DSO market model	Integrated flexibility market model
Interaction between system operators	Adequacy of existing communication channels, including the use of common data	High	Medium	Medium	Low	Medium
Grid operation	Respecting distribution constraints	Low	High	High	High	High
	Use of resources from the distribution grid by the TSO	High	Medium	Low	High	High
	Recognition of the evolving role of the DSO	Low	High	High	High	High
Market operation	Possibility to lower market operation costs	High	Low	Low	Medium	Medium
	Liquidity of the market	Medium	Low	Low	Medium	High
	Economies of scale	Medium	Low	Low	High	High

Figure 2 – Summary of characteristics for SmartNet coordination schemes.

Analysing the outcomes of the project, some key points have been delineated in order to understand the impact of these schemes in TSO and DSO grid operation as well as the impact on market participants. According to SmartNet results, the choice of the coordination scheme to be used is then dependant on some key aspects:

- Effectiveness of TSO-DSO coordination schemes depends on level of services requested by the DSO:
  - In case of few congestions at distribution level (forecasting errors are comparable to the possibility of having congestions in distribution grid), CS A has higher economic performance with respect to CS B and CS D;
  - When distribution congestions are significant (and predictable), the adoption of CS B or CS D results to be beneficial.

  Thus the choice of an appropriate coordination scheme is dependent on factors such as the type of ancillary services, normal operation or emergency situations, the amount of RES installed and the current market design.

- The implementation of two-steps markets (including all solutions which considers two separate markets for local and global services) is generally less efficient than optimizing in a single step (capable of

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considering both TSO and DSO needs – CS D). Anyway, in the short-term period, the development of separate markets is a more viable solution and, especially, implementation costs and efforts are lower.

- From the simulations, according to the assumptions made by the project SmartNet, it appears that the overall coordination among different stakeholders has to bear significant IT costs: management of DERs, aggregation software, updates in optimization algorithms. IT costs in different CSs resulted almost the same and much lower than operational costs.
- Different coordination schemes see different roles for the DSO, from no procurement of flexibility at all up to having the balancing responsibility on behalf of the TSO, thus the choice of a specific coordination scheme could represent the starting point of a gradual increase of responsibilities of the DSO. A country, depending on the national framework, can evolve from one coordination scheme to another. Several schemes are mostly based on a common market architecture, thus an evolution is always possible.

3.2. Interrface

The INTERRFACE [2] project aims at designing, developing and exploiting an interoperable pan-European Grid Services Architecture (IEGSA) to act as the interface between the system operators (TSO and DSO) and the final users. Furthermore, the platform helps stakeholders in performing coordinated activities such as the use and procurement of common services. The development of the platform is based on a previous analysis and design of new services and markets in order to capture the effects of evolving energy markets and services ensuring the active participation of each stakeholder. In a first moment, the analysis follows a top-down approach where services to implement are defined together with actor roles and interactions and, finally, the procurement mechanisms are described for each of them. Following a schematic approach, with reference to Figure 3, the INTERRFACE project addressed the following phases of market interactions [3]:

Prequalification

Certification provided to resources when they have the possibility of executing services. This is dependent on the capability of the flexible resources and the local network limitations.

Reservation of available capacity

Reserve dimensioning (on the basis of imbalance and congestion forecasts) and reservation of selected flexible resources.

Procurement of energy products

Process aimed at selecting the available resources (by evaluating dedicated merit order lists) for the execution of a service.

Activation

Process triggered by aggregators and aimed at modifying the operation mode of flexibility units in order to provide the service.

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Settlement

Process aimed at remunerating flexible resources and distributing costs according to responsibilities.

In a second phase, the top-down analysis is combined with the results of the bottom-up analysis of the sequence market diagrams used in the demos resulting in categorizing and classifying possible market structure and interactions for ancillary services, such as congestion-management (CM) and balancing markets. Some options consider separating the procurement of congestion management services from the balancing services (1A, 2B - Figure 3):

- *Market option 1A*:
  - Separated TSO and DSO CM-markets
  - Dedicated Merit Order List (MOL) for each CM market
  - Three different sequential schemes: DSO CM-market closes before TSO CM-market, the opposite or DSO and TSO CM-markets run simultaneously

- *Market option 2B:*
  - Fully integrated TSO and DSO CM-markets.

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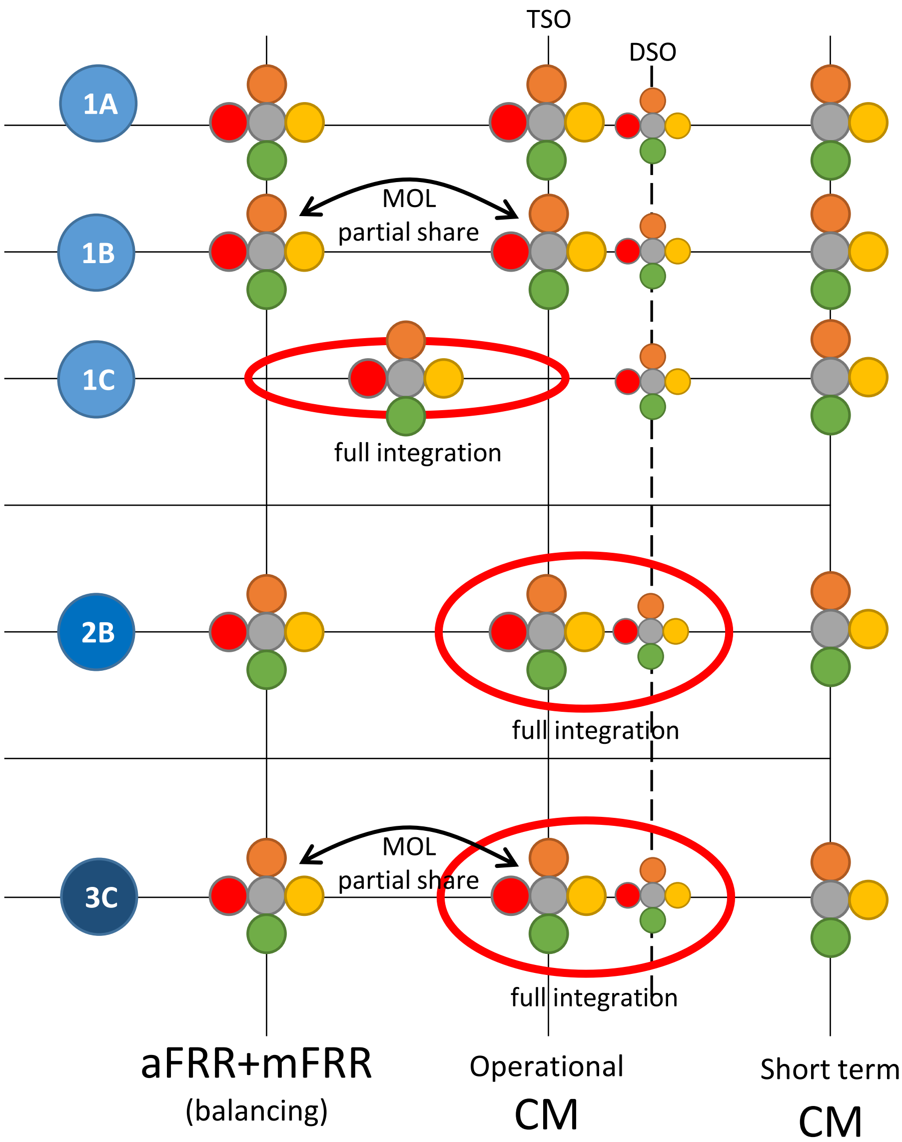

Figure 3 – Summary of market schemes from EU project Interrface (CM: congestion management; aFRR: automatic frequency restoration reserve; mFRR: manual frequency restoration reserve; MOL: Merit Order List)

Advantages of separate markets are the possibility of designing products and services according to the system operator needs; on the contrary it is necessary to establish some interactions to avoid those actions of one grid operator that may cause congestions for the other involved operator. A common market, instead, produces a natural coordination process where resources are optimized to solve both TSO and DSO needs, but the product design should look at the different necessities of TSO and DSO.

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Options 1B and 1C (Figure 3) introduces possible integration of CM-markets with balancing markets:

- *Market option 1B*:
  - Separated TSO and DSO congestion management (CM) markets
  - Dedicated Merit Order List (MOL) for each CM market
  - Transmission CM-market can possibly access to balancing MOL

- *Market option 1C*
  - Separated TSO and DSO congestion management (CM) markets
  - Dedicated Merit Order List (MOL) for each CM market
  - Transmission CM market and balancing market are integrated (access to the same MOL).

Having a CM-market integrated with the balancing one can be limiting in terms of resources requirements, it should be defined specifically that resources can participate anyway even if they can only offer balancing services or congestion management services. Furthermore, procurement of balancing products needs to consider the fact that some resources are blocked/reserved by CM services. The settlement phase should consider separately the costs for balancing and CM. Anyway, a full integration (option 1C) during the procurement phase could help in identifying an optimal set of activations with respect to the estimated needs.

3.3. CoordiNET

The CoordiNet project [4] aimed to demonstrate how DSOs and TSOs should act in a coordinated manner to procure grid services in the most reliable and efficient way through the implementation of three large scale "TSO-DSO-Consumer" demonstrations, in cooperation with market participants (and end users). The main objectives were to demonstrate the activation and provision of services through a TSO-DSO coordination and to define and test standard products that provide services to the network operators.

A mapping of coordination schemes has been proposed by introducing **classification layers** that highlight the differences between the coordination schemes. The different identified classification layers were:

- NEED: the need to be fulfilled by flexibility (local/central needs)
- BUYER: Which stakeholder(s) buy(s) the flexibility to answer a certain need (TSO, DSO and commercial parties)
- MARKETS: the number of markets considered (single market or multiple markets)
- RESOURCES: If the TSO is allowed to procure flexibility services outside its own monitored area of control.

Going through the different classification layers resulted in seven groups of coordination possibilities, depicted in **Figure 4**:

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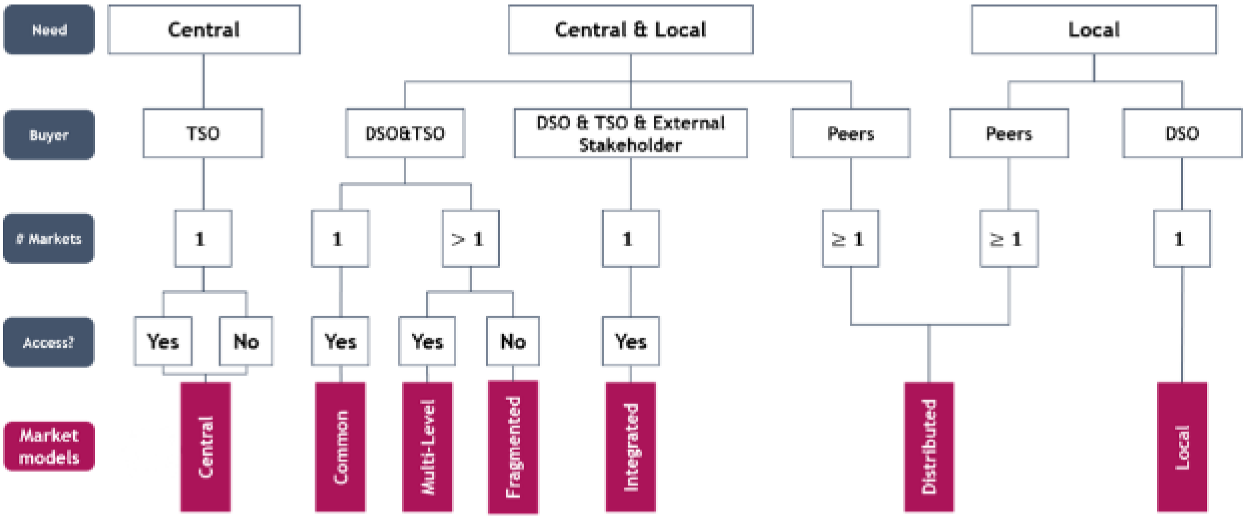

Figure 4 – Different TSO-DSO Coordination Schemes defined in CoordiNet, deliverables D1.3 and D6.7 [4]

Considering the grid services of *Balancing*, *Congestion Management*, *Controlled Islanding* and *Voltage Control*, the relevant Business Use cases has been identified for the three demo countries (namely Greece, Spain and Sweden) depending on the applied coordination scheme (see **Figure 5**).

Figure 5 – Overview of Business Use Cases identified in the CoordiNet Project, deliverable D5.1.

The three demonstration campaigns tested different products in different time frames. Figure 6 presents the overview of products, system services, timeframes and coordination schemes implemented in the CoordiNet demonstration activities (Spain in pink, Sweden in yellow, and Greece in grey).

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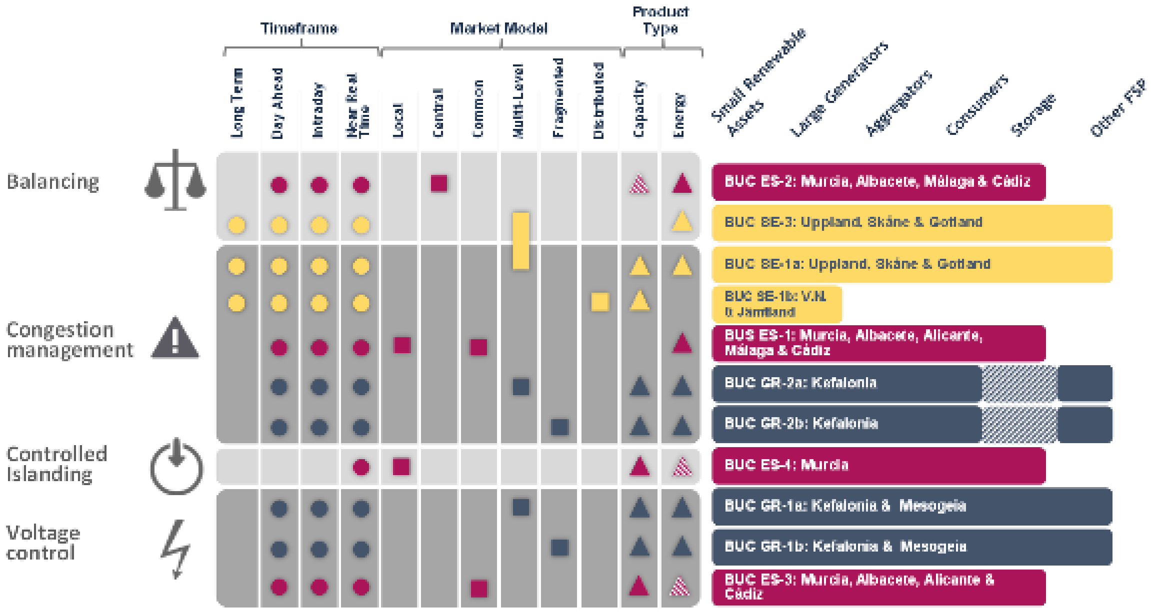

Figure 6 – Overall CoordiNet approach [4]

An evaluation of relevant combinations of services and coordination schemes, using supporting market simulations as well as analytical, numerical and qualitative analyses to complement the findings of the demonstrators, pointed out that, in an efficient market, i.e. with optimal utilisation of DERs, low coordination efforts and interoperability challenges reduced, the *common market* would be the most efficient and least costly market model (from a procurement cost perspective). However, this market model has higher requirements in terms of activation time, minimum bid size, communications, etc. which can be a barrier for some small resources (a harmonization in requirements for participation should be implemented to allow small-scale resources to participate). The common market model also may require a significantly longer computational time for the optimisation algorithm. For these reasons, in the early stage of development of flexibility markets, the simpler mechanisms represented by separate markets could be recommended.

It worth mentioning that, based on the project findings, the efficiency of coordination schemes with sequential markets (i.e. Fragmented and Multilevel), under certain conditions (mostly related to the pricing), have the potential to converge to the efficiency of the common market, while having lower needs in terms of network information sharing.

3.4. PLATONE

The Platone Project [5] aims at defining new approaches to increase the observability of renewable energy resources and of the less predictable loads while exploiting their flexibility. The main goal of Platone project is to provide a cost-effective, seamless and secure power supply for their customers as active players while

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supporting the TSO in their system level responsibilities. Platone develops a two-layer platform for distribution network operation and market operation creating a seamless integration of local prosumers in an open market structure.

The processes of *Congestion and Voltage Management*, tested in the Italian pilot, are divided into different phases. The identified main areas regarding the development of these services are:

- Information exchanged
- Interaction and coordination between system operators
- Interaction between system operators and market parties

Figure 7 illustrates the main phases of the process with respect to the market-based solutions, adopted in Platone Italian demo and are described below.

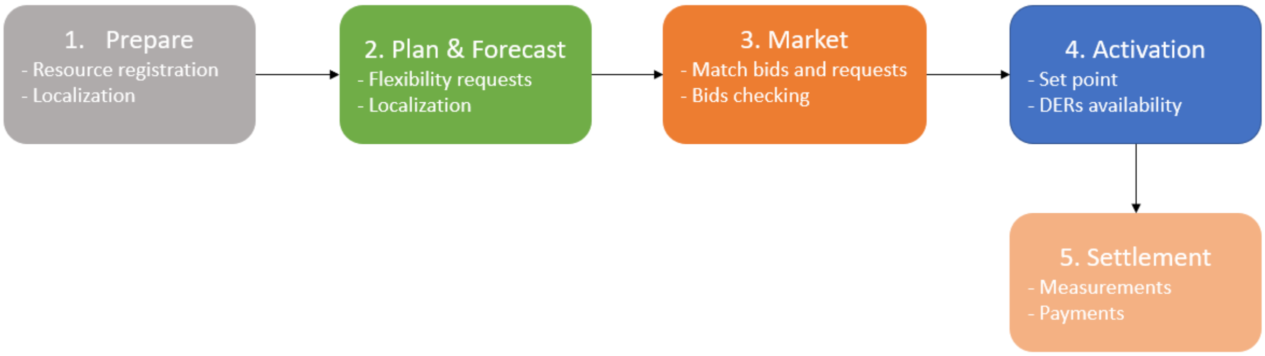

Figure 7 – Main phases of Platone Italian Demo

1. Preparatory phase: includes the registration and the localization of the resources. In the registration the Aggregator defines the services that the unit can perform according to the requirements set by the system operator and grid localization, to determine where the resource is able to deliver energy. Once the services and the providers are qualified, the system operators can use the bids of these parties to solve the network issues.

2. Forecasting phase: the system operators plan the grid utilisation forecast (day-ahead and near real rime) defining the flexibility requests that can be used for dealing with the issues. Forecasting is undertaken in different timeframes, so the accuracy of the predicted flow of electricity in a certain area improves as the time passes. The forecasts are updated and performed up until real time sessions (using real-time weather data and remote monitoring devices on the grids). It is necessary for system operators to have access to good schedules with relevant locational information, to perform proper forecast for grid management and make efficient and secure decisions.

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3. Market Phase: the bids and the requests can be collected and matched for day ahead session and for soft real time sessions. The available bids are efficiently sorted in a merit order list to ensure economic efficiency. Afterwards, the technical evaluation of the bids is done by the DSO checking the local grid limits.

4. Activation Phase: After collecting and evaluating the bids in the market phase, the flexibility bids are activated, sending the set-points to DERs located in the critical area and the congestion or the voltage violation is monitored. The evaluation of the bids will be continued also after activations, so that a granular monitoring of the energy moved is guaranteed. This is done based on real-time measurements.

5. Settlement Phase: The measurements of the activated flexibility should show whether the service is delivered. When a service is delivered by the Aggregator the amount of flexibility must be established, and the flexibility must be paid by the system operator. If the service is not delivered or does not respect the agreed parameters, a penalty is possible. The amount of flexibility delivered is determined by evaluating the data coming from smart meter at the connection point and compared with a baseline. The baseline is the total energy, without the flexibility invoked. The difference between the baseline and the measurements is allocated to the Aggregator.

The Italian Demo Architecture is shown in **Figure 8**.

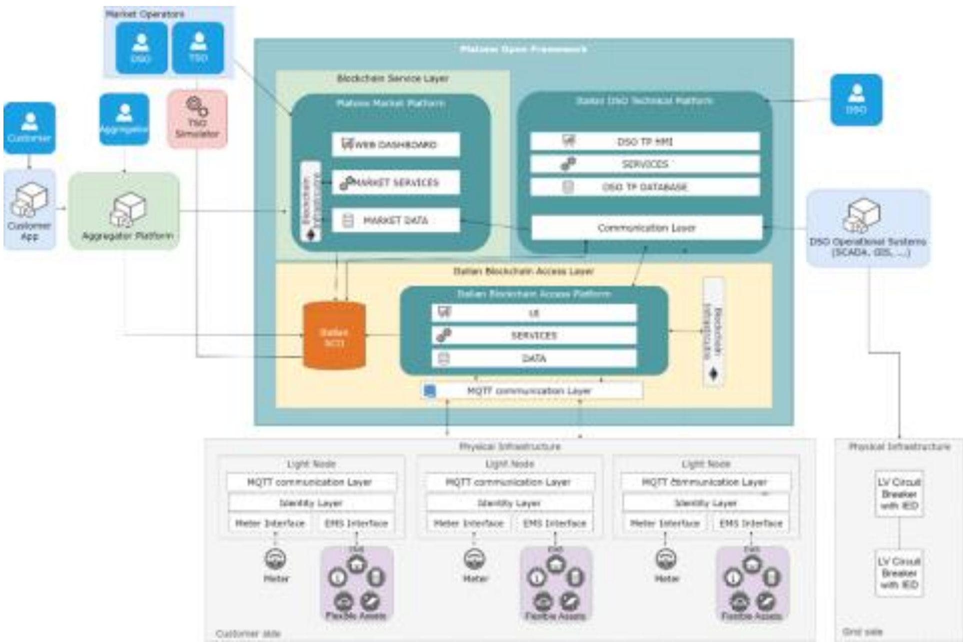

Figure 8 – Italian Demo Architecture in Platone Project

The system architecture adopted in the Italian demo of Platone Project can be traced back to the Smartnet scheme named "CS E – Integrated flexibility market model" illustrated in Figure 2.

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A short description of main technologies (devices, assets) used in the Italian demo and their characteristics are provided below:

- Shared Customer Database (SCD): Database that gathers all the data and services of flexibility resources and shares them with all the stakeholders;
- Light Node: Device installed on the DSO's smart meter in order to read, arrange, certify in Blockchain (at first level) and send to the SCD measurements and other data for the flexibility market and observability. Moreover, the device receives set-point from DSO Platform and make it available to client on client's apparatus (e.g. EMS);
- Energy Management System (EMS): A system, in customer premises, used to monitor, control, and optimize the energy consumption and production. It could include the Building Energy Management System (BEMS) for tertiary sector, the Home Management System (HMS) for residential users, the Battery Management System (BMS) and the management system for EV charging points;
- Operational Systems (OS): they comprise all the systems used by the DSO for the network control (GIS, SCADA, AMI and ERP);
- TSO simulator: Tool that emulates the TSO flexibility requests involving the resources connected in medium and in low voltage;
- Sensors: devices installed on the field to measure electrical quantities for the grid monitoring;
- Flexible Resources: hardware components installed on customers' premises, that provide flexibility to the market (e.g. generation plants, electric vehicles, batteries);
- Aggregator-Customer *App*: Application aimed at increasing awareness and involvement of customers within the flexibility market.

3.5. Regulatory pilots developed In Italy

3.5.1. RomeFlex

With ARERA's Resolution 372/2023 on August 3rd, 2023, Areti received approval for the RomeFlex project developed in response to the previous resolution 352/2021. RomeFlex (Reshaping Operational MEthods to run grid FLEXibility) allows for the creation of a complete, evolved and inclusive Local Flexibility Market to serve all the users in the City of Rome managed by Areti[1].

The RomeFlex project 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 possibility for BSPs and all other stakeholders to bid and to provide flexibility services

[1] Details of Areti project proposal can be consulted at https://www.areti.it/conoscere-reti/innovazione/progetto-romeflex

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during specific time slots. RomeFlex uses blockchain technology to guarantees 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 actually rendered and possibly, when provided, also for the availability to provide the service.

3.5.2. EDGE

ARERA Resolution 352/2021 [6] asks DSO for pilot projects focused on supply of local ancillary services aimed at identifying proper services characteristics and planning methodology, as well as appropriate solutions for procurement and remuneration. E-distribuzione EDGE[2] (Energy from Distributed resources for the Grid management of E-distribuzione) project has been approved with Resolution 365/2023 on 3 August 2023.

The EDGE flexibility services are performed through regulation of active power for grid constraints management, with “conditional” activation model.

EDGE pilot project involves portion of the distribution networks of Cuneo, Benevento, Foggia and Venice. In cooperation with the University Consortium - EnSiEL[3], a cost–benefit analysis process has been set up to forecast grid criticalities (current and voltage) and define the long-term need (over 2024) of flexibility services to comply with.

Based on that forecast, competitive auctions shall be carried out to sign mid-term (seasonal) availability contracts with Service Providers (SPs). DERs should follow a pre-qualification process. The contracts will allow E-Distribuzione to request the provision of the service in a specific area, during the availability window, following the short-term forecast of critical conditions on the network.

The remuneration scheme will compensate maximum capacity made available by SP (“price for availability”) and the actual provision of the service following single activations (“price per use”).

3.5.3. Pilot project on TSO-DSO Coordination (Traffic Light Mechanism)

In the Italian regulatory framework, the concept of TSO-DSO coordination was born following the publication of Resolution 300/17 [7], which defines the criteria for allowing not already qualified demand and generating units (such as those non-programmable renewables and aggregated distributed generation) the opportunity of ancillary services market (ASM – MSD in Italy which stands for ‘*Mercato dei Servizi del Dispacciamento’* where the reserve is procured and certain network constraints are resolved) participation: in this case, specifically for the participation of aggregate units (so called UVAM: virtually aggregated mixed units) in the UVAM Pilot Project, the DSO role is limited to the technical ex-ante validation of new resources (grid

[2] Details of e-distribution project proposal can be consulted at https://www.e-distribuzione.it/progetti-e-innovazioni/il-progetto-edge.html

[3] https://www.consorzioensiel.it/

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connection points) in the pre-qualification phase required for ancillary service market qualification. Consequently, with the publication of Resolution 345/23 (TIDE) [8]; DSO figure has evolved: it acquires the facilitator role in the global ancillary services procurement eventually close to real time, taking advantage of its network operating status knowledge, and exchanges additional data with the TSO, to expand the observability of power flows and resources on the distribution network.

According to the above regulatory framework, Terna, to fully extend the flexibility resources pool and to avoid indirect contingencies on the distribution grid, aims to introduce in current regulation and grid code an evolution of the TSO-DSO coordination mechanisms for the management of flexibility provided by distributed resources connected to distribution grids implementing the Traffic Light model for global services procured by the TSO, through a pilot project phase. In this specific coordination scheme, the DSO expresses resource (grid connection point) constraint and a grid constraint in terms of "power available per grid area" (*Capability for a DSO Perimeter*) to allow the flexibility activation of MV/LV connected resources without creating bottlenecks. Terna considers within the ASM these distribution grid constraints in the flexibility procurement processes needed for the correct and safe operations of the Electricity System. The application perimeter of the expected coordination involves all distribution connected flexibility resources notwithstanding whether they are physical units or virtual units.

This step forward, via a dedicated pilot phase, will leverage the already existing process for static DSO validation that is part of the UVAM pilot project process. On top of it, the mechanism foresees applying the possibility for DSOs to dynamically provide grid constraints on specific grid areas that will be considered by Terna during the clearing process of the existing ancillary services market. This will prevent the possibility that an activation of global flexibility services, requested by Terna, may cause a contingency on the portion of the distribution grid to which the activated resources are connected. On the other hand, the mechanism will ensure that the resources procured by Terna are actually "electrically" available meaning that the distribution grid has the correct capacity to host the activation requested by Terna. The TSO-DSO mechanism envisaged by Terna is to be applied to all resources that are connected to the distribution grid, or portions of it, and regardless of the service they provide (as long as it is market based and procured by the TSO for balancing and grid congestions). The SPs will use the Crowd Balancing Platform (CBP), a blockchain technology-based platform aimed at facilitating the participation of small distributed resources to the energy markets, to handle the registration/prequalification of resources/resource groups and DSOs will use the CBP to provide static validations at resource level (*Static Traffic Light* - STL) and dynamic constraints at grid portion level (*Dynamic Traffic Light* - DTL). The data will be transferred to the TSO for appropriate consideration within internal market tools. Parties involved by the coordination mechanism will also be informed via the CBP of all relevant information necessary for their operations.

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4. Use Cases mapping

This section presents the coupling of the Business Use Cases (BUC), System Use Cases (SUC) and services for each investigated Italian pilot. Firstly, a brief description of the BUCs of interest to DEMO 1 is given, then each association with the Italian pilots is organized schematically and clearly in a table form.

It's worth underlining that the selected BUCs and SUCs could be refined further in a later stage of the Italian Demo, for two reasons: firstly, discussion on BUCs and SUCs is still ongoing in the BeFlexible Project at the due delivery date of this document. Secondly, as mentioned in par. §3.5 the "regulatory sandbox" pilots at national level have not started their operational phase, then it's not possible to identify what will be implemented in the real field and which processes will be simulated.

4.1. Summary of BUCs of interest

BUC04 – Long-term distribution grid congestion management: in this BUC integration of flexibility into DSO grid planning processes is described and analysed under the informative point of view (required information) and for flexibility activation (DER PGUI signals). The BUC considers all necessary coordination among DSO, forecast providers, SP/aggregator and DER.

BUC06 – Short-term congestion constraints forecasting and management for local flexibility service activation: it concerns the possibility of DSOs to forecast congestion in the short-term (from a month ahead up to real time) and to procure and activate flexibility services to manage them.

BUC07 – Short-term voltage constraints forecasting and management for local flexibility service activation: it considers the possibility to compensate for local voltage violations using the available flexibility in the day-ahead or intra-day operation. DSOs are responsible for the procurement and management of flexibility products which are able to provide the necessary services.

BUC08 – Crowd Balancing Interoperable data exchange between stakeholders: The Crowd Balancing Platform (CBP) is a blockchain-based system available for sharing information between TSO, DSOs and BSPs in a trusted and secured way. The Business Use Case describes how TSO, DSOs, BSPs can register flexibility resources and exchange data via the Flexibility Register functionalities during the resource prequalification process, facilitating TSO-DSO common information exchanges and BSP participation through a single channel for multiple markets access. Moreover, it supports transactions for market operations and Traffic Light data exchange between stakeholders enabling secure coordination between local markets and global market.

BUC09 – Local and global market coordination for distributed resources system service provision: TSO and DSO have to coordinate the procurement processes for the shared distributed resources, namely those resources which are able to provide both local and global services. The coordination during the markets phases among the involved actors aims to efficiently allocate the resources available avoiding over-procurement, network constraint violation and striving for overall economic overall efficiency. The BUC

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describes the different steps: 1) prequalification of the resources providing flexibility services, 2) Market base procurement, 3) flexibility activation and real time information exchange and 4) service settlement.

BUC10 – Dynamic constraints management for global flexibility activation in transmission system operation: it aims at enabling the use of resources connected on the distribution grid while avoiding indirect contingencies on the distribution grid. The coordination process takes the name of *Traffic Light Mechanism* where DSOs express capacity limitations of predetermined grid portions to allow flexibility activation for global purposes without creating bottlenecks.

BUC 11 – Capitalizing on flexibility available by leveraging on water distribution network assets: it consists in studying the behaviour of water distribution assets and define the process to monitor them (including tools and devices to provide flexibility). Then the possibility to estimate the amount of flexibility that can be provided for electric grid purposes. The BUC goes through the definition of the coupling of water and power systems following some steps: 1) Study of the behaviour of water distribution assets, 2) defining the process to monitor flexibility assets, 3) quantify flexibility potential to make it available to electrical grids.

In Table 1 all BUCs are listed, and the one relative to the Italian fast-track DEMO are paired with the respective pilots.

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Table 1 – Business Use Cases and Pilot association

Business Use Cases (BUC)	Italy		
	Pilot 1.1	Pilot 1.2	Pilot 1.3
BUC 1. Planning and sizing of energy communities considering customer flexibility			
BUC 2. Operation, energy sharing and flexibility boosting of local energy communities			
BUC3. Optimal control of domestic thermal loads to reduce costs and boost flexibility			
BUC 4. Long-term distribution grid congestion management		■	■
BUC 5. Aggregation for TSO and DSO grid services			
BUC 6. Short-term congestion constraints forecasting and management for local flexibility service activation	■	■	■
BUC 7. Short-term voltage constraints forecasting and management for local flexibility service activation	■	■	■
BUC 8. Crowd Balancing: Interoperable data exchange between power system stakeholders	■	■	■
BUC 9. Local and global market coordination for distributed resources flexibility	■	■	■
BUC 10. Dynamic constraints management for global flexibility activation in transmission system operation	■	■	■
BUC 11. Capitalizing on flexibility available by leveraging on water distribution network assets	■		
BUC 12. Operating a value chain enabler for flexibility-centric and non-energy services			
BUC 13. Combine energy services (production, storage) with mobility			

4.2. DEMO Mapping: BUC, SUC and service relations within the Italian pilots

Table 2 summarizes the BUCs with relative SUCs that were preliminary selected in the specific pilots of the Italian Demo, correlating them to the services identified in the GA and selected for demonstration.

As mentioned before, in a later stage of WP4, the processes implemented in the real field and the simulated processes will be identified.

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Table 2 – Pilots Mapping vs SUCs

Business Use Case (BUC) Task 1.4	System Use Case (SUC) Task 3.1	BeFlexible Service	Technology Provider	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	Long-term Congestion Management at the distribution level *GA Service 24: Congestion Technical grid constraints forecasting service for local flexibility service activation* *GA Service 25: Voltage Technical grid constraints forecasting for local flexibility service activation*	EDI/ENEL/GSP	Pilot 1.2 (Foggia, Benevento), 1.3 (Cuneo)
BUC06. Short-term congestion 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	Local Congestion Management at the distribution level *GA Service 19: Congestion forecasting service*	ARETI/RWTH	Pilot 1.1 (Rome)
	SUC06.3 – Settlement of flexibility services from DER participating to local market	*GA Service 19: Congestion forecasting service* *GA Service 24: Congestion Technical grid constraints forecasting service for local flexibility service activation*	ARETI/RWTH EDI/ENEL/GSP	Pilot 1.1 (Rome), 1.2 (Foggia, Benevento), 1.3 (Cuneo)
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	Local Voltage Constraints Management at the distribution level *GA Service 21: Voltage control (day ahead, intra-day, real-time)*	ARETI/RWTH	Pilot 1.1 (Rome)

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Business Use Case (BUC) Task 1.4	System Use Case (SUC) Task 3.1	BeFlexible Service	Technology Provider	Pilots
	SUC06.3 – Settlement of flexibility services from DER participating to local market	*GA Service 21: Voltage control (day ahead, intra-day, real-time)* *GA Service 25: Voltage Technical grid constraints forecasting for local flexibility service activation*	ARETI/RWTH EDI/ENEL/GSP	Pilot 1.1 (Rome), 1.2 (Foggia, Benevento), 1.3 (Cuneo)
	SUC07.4 – Online monitoring and observability enhancement to quantify the actual voltage condition	Grid Monitoring and observability *GA Service 23: Real-time monitoring for system awareness* *GA Service 27: Improved grid observability service*	ARETI/RWTH EDI/ENEL/GSP	Pilot 1.1 (Rome), 1.2 (Foggia, Benevento), 1.3 (Cuneo)
BUC08. Crowd Balancing: Interoperable data exchange between stakeholders	SUC08.1 – Flexibility Register SUC08.2 – Market data exchange functionalities	Crowd Balancing Platform *GA Service 29: Balancing service provision with the demo resources*	TERNA ARETI EDI/ENEL	Pilot 1.1 (Rome), 1.2 (Foggia, Benevento), 1.3 (Cuneo)
	SUC08.3 – Traffic light data exchange functionalities SUC08.4 – Verification functionalities	Traffic Light mechanism *GA Service 22: Dynamic Grid Constraints* *GA Service 26: Dynamic Grid Constraints assessment to coordinate with TSO*		
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	Local and global market coordination *GA Service 28: Congestion management service provision with the demo resources* *GA Service 29: Balancing service provision with the demo resources* *GA Service 30: Other TSO services provision with the demo resources* *Service 31: Grid observability processes testing in the demo*	TERNA	Pilot 1.1 (Rome), 1.2 (Foggia, Benevento), 1.3 (Cuneo)

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Business Use Case (BUC) Task 1.4	System Use Case (SUC) Task 3.1	BeFlexible Service	Technology Provider	Pilots
	SUC10.3 – Bids placements and verification SUC06.3 – Settlement of flexibility services from DER participating to local market			
BUC10. Dynamic constraints management for global flexibility activation in transmission system operation	SUC10.1 – Ex-ante validation SUC10.2 – Constraints definition SUC10.3 – Bids placements and verification	Dynamic constraints management *GA Service 22: Dynamic Grid Constraints* *GA Service 26: Dynamic Grid Constraints assessment to coordinate with TSO*	ARETI EDI/ENEL	Pilot 1.1 (Rome), 1.2 (Foggia, Benevento), 1.3 (Cuneo)
BUC11. Capitalizing on flexibility available by leveraging on water distribution network assets	SUC11.1 – Evaluate the flexibility capability of water distribution networks		ARETI/ENG	Pilot 1.1 (Rome)

5. Technical specifications and testing scenarios

5.1. Characteristics of networks

The South-Mid EU Demo is composed by 3 pilots, representing different climate regions and load density areas. In **Figure 9** the association of the pilot numbering and relative geographical area can be observed and in Table 3 a generic description is given.

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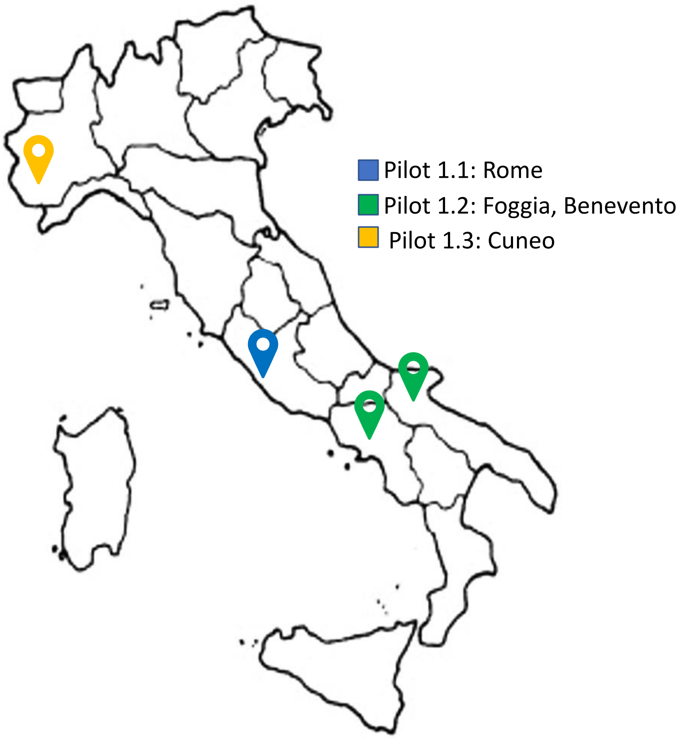

Figure 9 – WP4 pilots: Cuneo, Rome, Foggia, Benevento

Table 3 – Generic description of pilot projects considered in Italy

Pilot 1.1 [ARETI] Rome (ITALY) – Cross-sectoral business involved (water, EVs, residential and industrial customers) Italy	
General information	
Location: Rome, urban context with high population density (2.8 M inhabitants & 1,285 kms), peak load of 2 GW in 2020 will grow to 3 GW in 2030 **Climate:** Pilot 1.1 [MDN] temperate Mediterranean climate	**Participants: TSO**: TERNA, **DSO**: Areti; **Tech. & research**: ENG, RSE, RWTH, **Engagement**: SOUL; **ETHICS &LEGAL**: TLX
PILOT technical description	
User Segmentation	**Profile of segments**: All the users connect in medium and in low voltage in the Rome's area can take part in the pilot. Accord to neutrality approach, promoted by the European Directive 2019/944, the customers with a connection power higher than 3 kW can provide

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Pilot 1.1 [ARETI] Rome (ITALY) – Cross-sectoral business involved (water, EVs, residential and industrial customers) Italy	
	flexibility to the grid, through an Aggregator that pools the resources to achieve a significant amount of flexibility. **Types of consumers**: Residential consumers living in buildings; Prosumers with PV on the roof that live in independent houses; Company EV fleets; CPOs that manage public and private rechargers; Industrial facilities. The first users involved, will be several prosumers equipped with a PV Plant (3 or 6 kW) and storage (2,5 to 5 kWh) and the Areti's Smart park composed by 10 stations with 2 AC EVSE (3 and 22 kW) to feed 20 EVs, 40 kW PV and 125 kWh energy storage. **Readiness of segments**: TSO: medium, DSO: medium, BSP already participating to TSO market: medium, Other potential BSP: very low, Non energy business actor: low. **Participation of local actors**: Generator, Industrial, Commercial and tertiary sector both MV and LV connected prosumers can participate directly or through an aggregator.
Type of loads	EVs, Residential applications, storages, residential and commercial HVAC.
Energy sources	Residential and utilities PV plants and storage; CHP plant; eventually EV point of charge with V2G technology.
Other info	Exploitation of BRIGHT Project data-driven cross-sector services for electricity network: capitalizing on flexibility available by leveraging on water distribution network assets (e.g. smart water pumps, water storage, wastewater plant operation) with a view to validate strategies, where the distribution grid issue could be harmonised with the water network electricity planning dispatching. As example, pumping water in water storage reservoirs or tanks and for a later usage of larger amount of water in the afternoon or evening during the water consumption peak. In such a case the available flexibility models can be trained with available data to identify the most suitable charge and discharge of water storage with a view to either optimize electricity network operation and/or provide aggregators with optimal and forecasted flexibility. To validate the coordination between market sessions (TSO and DSO marketplaces) the TSO/UVAM market perimeters related to the DSO involved areas will be eventually used as spatial reference for global flexibility services. A common 'flexibility register' proposal: database to store the DERs data, as technical characteristics, localization, qualification for services, validated measurement. This register has to be available to all the authorized stakeholder, it's the unique collector for the flexibility data to increase the trust and the transparency in the market. Power Grid User Interface (PGUI): device able to exchange in near real-time: 1) measurements from smart meter; 2) flexibility service activation command; 3) info for customers Behind the Meter EMS systems. The role of the flexibility

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Pilot 1.1 [ARETI] Rome (ITALY) – Cross-sectoral business involved (water, EVs, residential and industrial customers) Italy	
	register and its link with the Orchestration layer made available to Italian demos will have to consider the consistency of system wide databases and the role of the TSO as third party owner of already existing databases in compliance with Italian regulation.

Pilot 1.2 & 1.3 [EDI, ENEL] South Italy (Pilot 1.2) and North of Italy (Pilot 1.3) - Flexibility from aggregated distributed resources	
General information	
Location: Foggia and Benevento (Pilot 1.2) and Cuneo (Pilot 1.3), ITALY **Climate:** Pilot 1.2 [MDN] temperate Mediterranean climate, Pilot 1.3 [[ALS] Alpine South	**Participants:** ENEL; **TSO:** TERNA; **DSO:** EDI; **Tech. & research:** GDS, RSE; **Engagement:** SOUL, Innovation Norway; **ETHICS&LEGAL:** TLX
PILOT technical description	
User Segmentation	**Profile of segments**: All potential Balance Service Providers (BSP) located in the pilot project area for local flexibility services procurement. **Types of consumers**: All, no technology constraints for BSP. Customer engagement campaign for this demo is foreseen to recruit potential BSP al MV/LV level, interested in testing PGUI for DERs direct activation. **Readiness of segments**: TSO: medium, DSO: medium, BSP already participating to TSO market: medium, Other potential BSP: very low, Non energy business actor: low. **Participation of local actors**: Generator, Industrial, Commercial and tertiary sector MV/LV connected resources in the pilots area can participate directly or through an aggregator.
Type of loads	Local DSO market design is neutral regarding 'technology' providers. This pilot involves loads, Battery Energy Storage System (BESS) and generators able to provide the flexibility service. Positive Technical pre-qualification test enable the resources for DSO local market.
Energy sources	All, no technology constraints for BSPs.
Other info	To validate the coordination between market sessions (TSO and DSO marketplaces) the TSO/UVAM market perimeters related to DSO local market perimeters, identifying real and/or virtual connected DERs able to provide services, will be eventually used as spatial reference. A common 'flexibility register' proposal: database to store the DERs data, as

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Pilot 1.2 & 1.3 [EDI, ENEL] South Italy (Pilot 1.2) and North of Italy (Pilot 1.3) - Flexibility from aggregated distributed resources	
	technical characteristics, localization, qualification for services, validated measurement. This register has to be available to all the authorized stakeholder, it's the unique collector for the flexibility data to increase the trust and the transparency in the market. PGUI: device able to exchange in near real-time: 1) measurements from smart meter; 2) flexibility service activation command; 3) info for customers Behind the Meter EMS systems. The role of the flexibility register and its link with the Orchestration layer made available to Italian demos will have to consider the consistency of system wide databases and the role of the TSO as third party owner of already existing databases in compliance with Italian regulation.

Table 4 – Summary of network characteristics for WP4 demos

Pilot	Type of territory	Number of nodes in MV – MV/LV	Orientative customers power withdrawal	Orientative customers power injection
1.1 Rome	Dense urban	~25 AT/MT ~ 600 feeders	~580,000 users ~ 390 MW in MV ~ 600 MW in LV	
1.2 Foggia, Benevento	Urban-rural-Industrial	~20 AT/MT ~ 490 feeders	13.064 MW consumption 521.960 LV connections 1.490 MV connections	3.571 MW generation
1.3 Cuneo	Urban-rural-Industrial	~10 AT/MT 120 feeders	10.155 MW consumption 427.156 LV connections 2.025 MV connections	3.247 MW generation

5.1.1. Characteristics of networks of Pilot 1.1

The information reported in the previous table, describe the area involved in RomeFlex project. This portion of the grid is divided in two MV level: 20 kV and 8.4 kV. However, the loads fed by this grid is very high, already now, and the increase of the electrification expected in the next years could cause local congestions. Indeed Areti, based on internal analysis, expects 600 MW of installed power from EV charging points and 400 MW from heat pumps. To accommodate this scenario, the flexibility provided by the local resources is crucial.

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5.1.2. Characteristics of networks of Pilot 1.2 and 1.3

The perimeter of interest of the EDGE pilot project, adopted also in BeFlexible, was identified in portions of the networks supplying the provinces of Foggia and Benevento (pilot 1.2) and Cuneo (pilot 1.3). These portions of the network potentially critical were chosen in relation to the analysis of the expected scenario (rapid evolution of customer connections) and the possibility of exploiting flexibility services. Overall, the selected areas include medium and small urban areas, agricultural, industrial and mountain areas.

5.2. Flexibility assets

The different typologies of Flexibility assets that could be involved in the Italian demo are below represented in **Table *5***.

Table 5 – Flexibility assets in Demo I

	EV recharge stations	Heat pumps	Water infrastructure	Distributed generation – PV	Distributed generation – other
1.1 Rome	✓	✓	✓	✓	✓
1.2 Foggia, Benevento	✓	✓		✓	✓
1.3 Cuneo	✓	✓		✓	✓

5.2.1. Flexibility assets for Pilot 1.1 Rome

The Areti pilot aims to test different kind of DERs connect to distribution network, with a special focus on the small-sized users. In Rome Demo a DER is a user plant composed by one or more elements under the same Point of Delivery (POD), as: production power plant, consumption units, battery energy storage systems and electric vehicle charging points with V1G or V2G technology. The Balance Service Provider (BSP) gathers the flexibility from the DERs and sells it to the market.

The DER can provide flexibility services individually or collectively in a Dynamic Pool defined by DSO. To provide local ancillary services, the DER must be associated with a single POD and must be equipped with a device named PGUI to certify quarter-hour measurements and market outcomes.

Typical assets in a DER useful for the supply of the services are:

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- Charging points for electric mobility
- Heat pumps
- Residential and industrial storage systems
- Production unit.

The services can be provided by any asset regardless of technology, however the potential flexibility available to the distribution network is mainly delivered by the following technologies: programmable storage, modular users (appliances, water heaters, heat pumps...), cogeneration plant, V1G charging stations, anything else able to provide flexibility to SOs.

The flexibility potential identified by these assets is extremely broad: thousands of electric vehicles charging stations already exist or are being activated and more than 300 PV plants equipped with storage are activated every month.

5.2.2. Flexibility assets for Pilots 1.2 Foggia & Benevento and 1.3 Cuneo

The e-distribuzione pilots 1.2 & 1.3 will leverage the Flexibility assets involved in the EDGE regulatory pilot.

Within its Regulatory pilot, e-distribuzione uniquely defined ex-ante Flexibility Perimeters, based on the forecast of critical issues and the sizing of the flexibility product useful for resolving them, providing the list of PODs present therein. The flexibility services, to be regulated through long/medium term bilateral contracts, will be supplied through competitive tenders carried out through an external market platform and all resources present in the Flexibility Perimeter (production units, consumption units, storage units, electric vehicle charging systems) could be able to participate. Therefore, for the pilots 1.2 & 1.3, ENEL is waiting for the outcome of the tenders established by EDGE project to select some of the flexibility providers to be engaged for BeFlexible.

6. Coordinated flexibility procurement process

In line with many EU projects (Section 3), the operation of parallel flexibility procurement mechanisms governed by the DSO and the TSO for either local flexibility services or global flexibility services is proposed. DSO can procure local flexibility services (LFS) in many ways, such as long-term contracts, short-term markets or a combination of both; whatever the chosen option is, DSOs are responsible for procuring flexibility services in the most cost-efficient way possible. Same applies for the TSO and the ancillary services market which serves the purpose of procuring reserve, balancing and congestion management products (other services'/products' procurement is not market based and follows the grid code requirements or other contractual arrangements). For simplicity within this document, procurement mechanisms will be referred to as *Local Flexibility Planning (LFP)* for DSO or *Global Service Market (GSM)* for TSO, taking into account the presence of the following process sections: registration; prequalification; market and planning phase; monitoring, activation and settlement. Despite the TSO GSM (MSD in Italy) being operated on a continuous basis for the sake of secure operation of the electricity system, LFP can be triggered on occurrence when the

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DSO forecasts congestions on grid elements and identify the necessity of activating flexibility services. This model is designed starting from the so-called *multi-level market model* given in CoordiNet [4]: it considers two separate buyers of flexibility (TSO and DSO); one or more market sessions belonging to different market-based frameworks are used to procure flexibility; and TSO has the possibility to access distributed flexibility assets. The description of the procurement mechanism is divided into steps (registration; prequalification; market and planning phase; monitoring, activation and settlement) and a coordination mechanism is defined between TSO and DSO to regulate the procurement/activation of flexibility, in particular in the condition of shared resources (Figure 10).

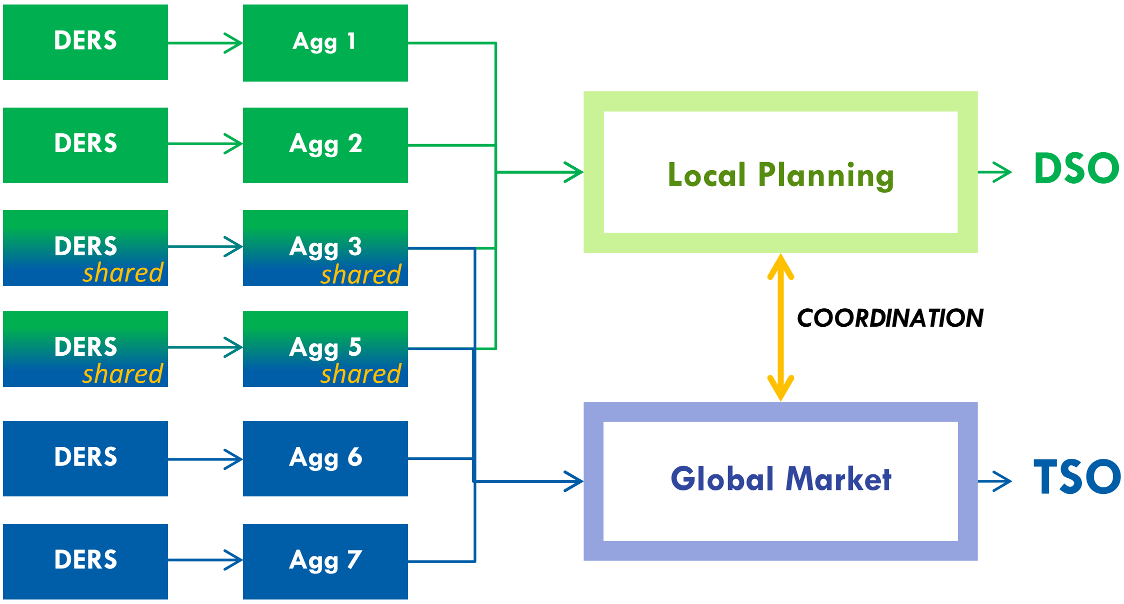

Figure 10 – General overview of market separation

6.1. Registration and grid prequalification of flexibility assets

The registration phase represents the process during which SPs sign up and share information (as for example the ones indicated in Table 6) about their assets/resources with SOs in order to start the grid prequalification process of the asset providing flexibility services. In theory, given the differences between DSO and TSO markets, to provide local and global flexibility services, the SP would need to undergo a double registration, on both TSO and DSO platforms. In order to simplify and unify registration procedures for SPs in the Italian DEMO, a common registration mechanism is established leveraging the Crowd Balancing Platform (CBP) and his data registry functionalities (as built in its Flexibility Register module), which contains all the functionalities needed to perform the registration and prequalification activities. The CBP will be integrated with SOs back-end systems to exchange data, thus the registration phase is carried out by SPs only once through a single-entry point. Some information about these platforms concerning their functionalities and

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interactions are given in Chapter 7, furthermore they will be investigated then during the *DEMO preparation*, defined in Task 2 of BeFlexible WP4.

After the SP has registered the resources through the CBP's Flexibility Register functionalities, the information is forwarded to the respective SO entitled to perform the ex-ante validation (grid prequalification as defined in [9]), also referred as *Static Traffic Light (STL)* in Italian pilot projects. This process is necessary to ensure that the resource flexibility indicated by SPs during the registration phase can be actually delivered, based on technical information held by the SO itself such as connection data, operating regulations and measures. Thus, the STL validates the flexible power of the resources registered by the SP confirming, modulating, or invalidating it. The grid prequalification process is carried out at grid connection point level and is a necessary step to carry on with the process moving to the definition of the pools of resources qualified in the market.

Table 6 – Example of information provided during registration phase

Information Group	Data	Description
Basic Information	ID Code	Identification code
	Category	Identification category
	Position	Geographic location (e.g. latitude and longitude)
	Others	[...]
Point of connection details	POD	Point of Delivery (alphanumeric code)
	Voltage level	Voltage level at the grid connection point
	Others	[...]
Available power for ancillary services	Upward active power	Amount of active power that can be modulated increasing the injection of energy (generation) or reducing the withdrawal of energy (load) from the grid.
	Downward active power	Amount of active power that can be modulated reducing the injection of energy (generation) or increasing the withdrawal of energy (load) from the grid.
	Activation period	Maximum time necessary to activate the resource after receiving the activation request.
	Others	[...]

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6.2. Product prequalification

The product prequalification procedure [9] is used to verify that SPs can indeed provide the services as promised by means of the registered resources or aggregate of resources (hereinafter recalled as *aggregates of DERs*). During prequalification it is checked whether the technical requirements of a product or service (some examples are given in **Table 7** and taken from attachments of technical reports of Italian pilots [10] and [11]) are fulfilled by the registered aggregates of DERs which are willing to provide services. The check consists of one or more technical test, defined specifically for the product and by each SO, to technically evaluate the possibility of an aggregate of DERs to satisfy service requirements. Both TSO and DSO are entitled of conducting the prequalification procedure for each DERs aggregate which subscribes to the provision of services within the specific SO market. To coordinate TSO and DSO processes and to simplify and streamline the process from the point of view of the SP, the principle of a *Table of Equivalences (ToE)* [9] is defined. The *ToE* is a tool able to cross-reference technical requirements giving the possibility of considering an aggregate automatically prequalified for a different product with respect to the one investigated during technical tests. Therefore, thanks to this tool, a single prequalification process could be conducted to qualify an aggregate in providing more than one service. Nevertheless, the product prequalification shall be repeated either periodically or if relevant changes have occurred to the technical characteristic of the flexibility asset (as explained in [12]). During product prequalification phase the first coordination mechanism between TSO and DSO is tested. The prequalification process gets started based on the registered data by the SP. The basic element in the registration phase is the grid connection point which is bundled together with others so as to define a pool of resources (aggregates of DERs) that can be prequalified to any market based on entry requirements. The prequalification process that the aggregate needs to undergo is based on the services the SP intends to deliver. If the service is not equivalent to any other, then the prequalification is performed by the SO that procures the service. If the Table of Equivalence applies then the service is the same (is provided with comparable requirements or a relation of inclusion exists among the services of different SOs) and the prequalification is performed by the connecting SO and, in case it has a positive outcome, the aggregate is qualified to all markets that procure the service the SP intends to deliver.

Table 7 – Possible attributes to define a product or service

Information Group	Data	Description
Location	DSO Perimeter	DSO region where the resources of and aggregate are connected.
Availability Window	Monthly window	Month in which the aggregate must be available to offer the service.
	Daily window	Day in which the aggregate must be available to offer the service.
	Others	[…]

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Information Group	Data	Description
Available power for the service	Upward active power	Amount of active power to modulate increasing the injection of energy (generation) or reducing the withdrawal of energy (load) from the grid.
	Downward active power	Amount of active power to modulate reducing the injection of energy (generation) or increasing the withdrawal of energy (load) from the grid.
	Others	[...]
Details	Activation time	Minimum notice time available for activation
	Recover Time	Minimum period between two subsequent requests of service.
	Others	[...]

Regarding the principle of Table of Equivalences set out above, it is important to specify that this is only applicable in the so-called 'pure case', i.e. when the two aggregates are the same as well as the service, the technical requirement and the test infrastructure.

Moreover four different aggregate conformations were identified, as summarised in Table 8. The assumptions underlying the construction of the table are:

1. an aggregate can access both Global and Local Market for all or part of its flexible power;
2. single DER can be included in two different aggregates enabled to provide both global and local services;
3. single DER may not provide services for both local and global markets at the same time, it may only provide a service to a single market at a given time;
4. if between a global aggregate and a local market aggregate there is a shared DER, then the BSP is the same.

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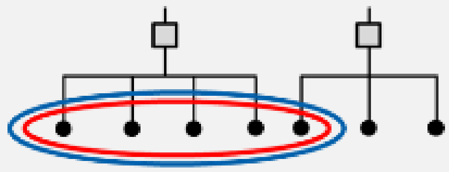
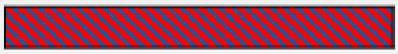
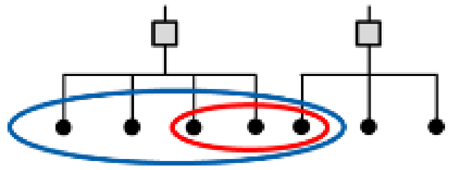
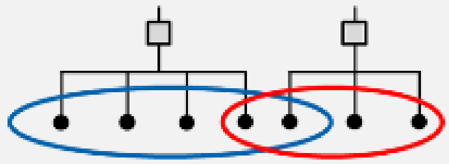
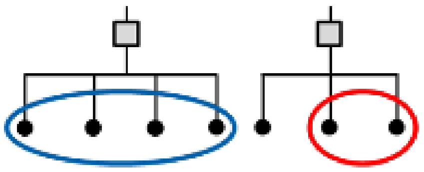
These assumptions are necessary to make integration between markets feasible for the following market, activation and settlement phases.

Table 8 – Aggregate configurations

Aggregates conformation	BSP	Flexible power	ToE applicability
	**Single BSP** for both aggregates	Global aggregate & Local aggregate 	Yes
	**Single BSP** for both aggregates	Global aggregate & Local aggregate 	No
	**Single BSP** for both aggregates	Global aggregate & Local aggregate 	No
	**Single or different** BSP for the two aggregates	Global aggregate & Local aggregate 	No

6.3. Market phase and/or planning phase

For Local Flexibility Services (LFS), the short-term planning process is triggered as a parallel process to the usual planning occurring in MSD. In the Italian DEMO, the timing scheme has been organized according to the actual structure of MSD. Regardless the scheme of the local service procurement, which could be represented by an actual collection of bids during a short-term market or by using pre-selected flexibility offers procured during long-term contracting, the LFP planning and the TSO-DSO coordination process is organized in 6 sequential sessions so as to mimic current market organization. TSO-DSO coordination only concerns market planning, real-time operation is handled autonomously by the respective SO.

Each session of the LFP closes before the TSO planning session for the same delivery period. The definition of this planning schedule helps in defining a preliminary hypothesis of market coordination which is based

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on the **principle of mutual unavailability** of shared flexibility assets, thus those assets which are enabled to procure both global and local flexibility services. The principle of mutual unavailability, as by this first hypothesis, consists of the exclusion from the following market sessions of the flexibility which has already been selected in previous sessions.

Referring to Table 9**¡Error! No se encuentra el origen de la referencia.**, LFP *day-ahead* is the first DSO planning session, which happens the day before (D-1) with respect to the day of delivery (D). During the LFP day-ahead, the planning of flexibility activation is carried out for every hour of D. In particular, the planning relative to the first four hours results to be the definitive planning (dark grey), while for the last twenty hours the DSO defines preliminary planning (light grey) which can be further updated by DSO. Basically, as can be observed, each session shares with other SO data related to the final planning (DERs to be considered unavailable for other SO services) for four hours and the preliminary one for the following hours up to the end of the day. The same market structure is observed in Table 9 to plan ex-ante session for global services procurement (blue and light blue cells).

More specifically, taking into consideration an aggregate of DERs providing local flexibility services and an aggregate procuring global services with some DERs in common (in **Figure 11** respectively AGG_1 and AGG_2), if AGG_1 is entirely selected during *LFP day-ahead* to procure services in the first hour of the day, thus AGG_2 can provide global services with units not included in AGG_1. Vice versa, if AGG_2 is entirely selected during *MSD-ex ante* to procure global flexibility services in hour 6, it is not possible to use DERs of AGG_1 (in this case all the DERs of the aggregate) during *LFP 2-intraday*. In order to avoid excessively limit to the available flexibility in the late markets, two basic rules have been introduced:

1. When the SP is notified of the selection of flexibility, if the aggregate of DERs is *partially selected*[4] in a market session, the remaining DERs can be offered to provide flexibility in the following markets.
2. The remaining modulation of point 1) should belong to a different DER, the same DER cannot procure simultaneously global and local flexibility services.

[4] "partially selected" indicates that the activation request does not match the maximum available flexibility, thus the SP can manage the DERs so that some of them can still participate in following markets to provide further services.

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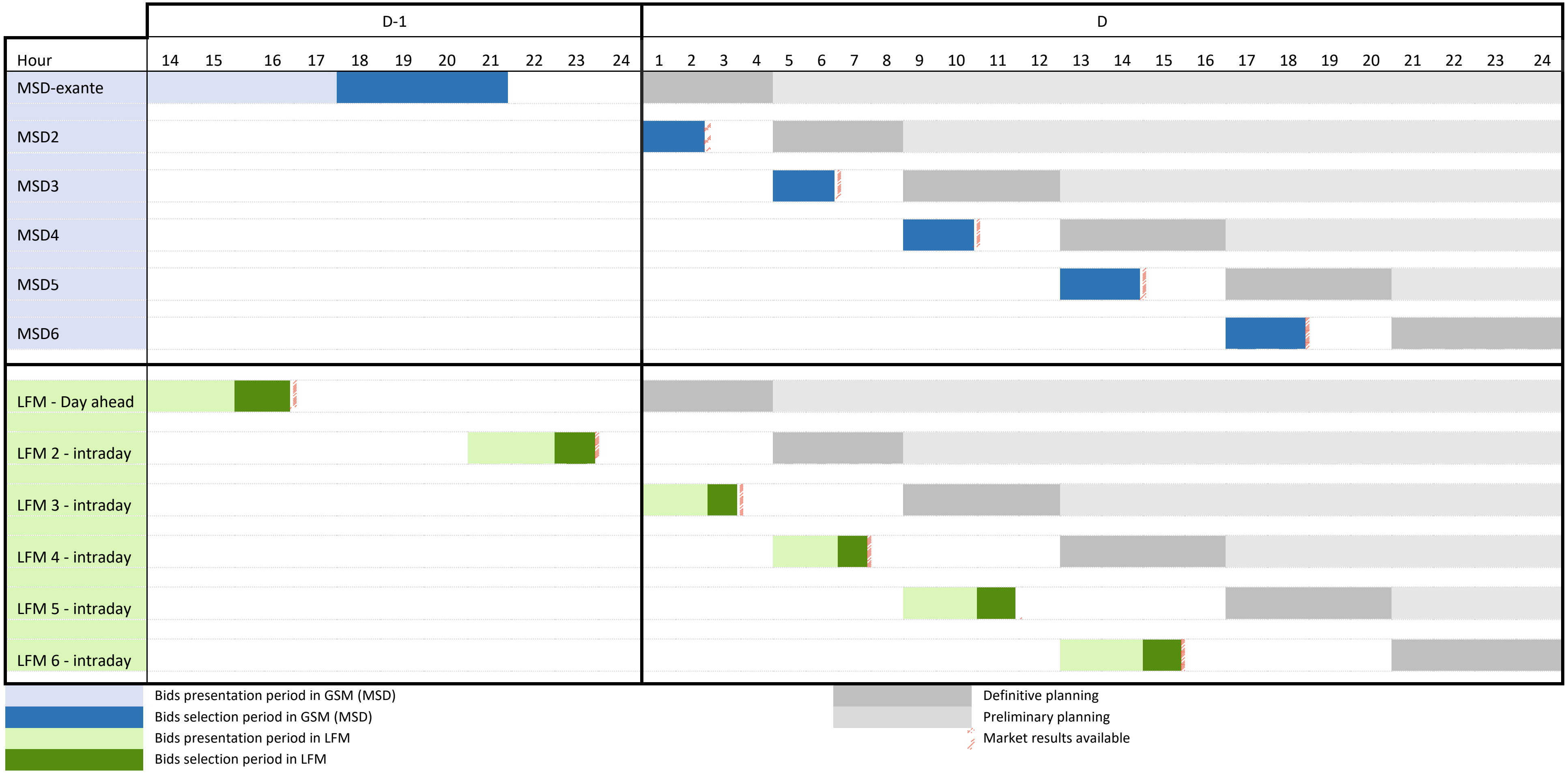
Table 9 – Global (MSD) and local (LFM) planning sessions in sequence



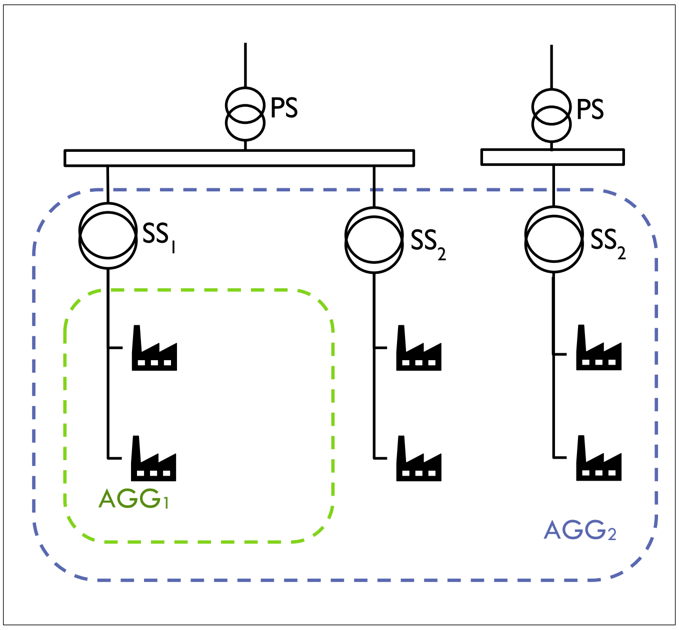


Figure 11 – Overlapping of aggregate of DERs procuring Local Flexibility Services (AGG_1) and UVAM procuring Global Services (AGG_2)

According to those two rules, it is responsibility of the SP to make available on the late markets only the flexibility not selected yet, indeed the SP is the only stakeholder which has all the information concerning which PODs will fulfils the service activation requests.

In this context, as reported in Section 3.5.3, the TSO-DSO coordination mechanism introduces a process to ensure that the flexibility offered by SPs and selected by TSOs can be delivered without causing an undesirable situation in either of the involved grids. This process is referred to as *Dynamic Traffic Light (DTL)*, where the possibility of the TSO to access distributed flexibility up to a maximum amount of adjustable power is verified by DSO. The DTL conceptually represents the process that examines at regular intervals the distribution grid status leaving to the DSO the possibility to set and update constraints for each delivery hour and for each DSO perimeter[5]. In the specific context of the Italian DEMO, the DTL factorises two elements: network status (colour and capability concerning each DSO Perimeter) and LFP activation planning.

Taking into consideration that electric grids are sized according to a utilization factor[6], it is plausible to consider that the grid bottleneck changes according to production and consumption forecasts. Therefore, in this DEMO the DSO perimeters can be updated in order to allow to maximize the available flexibility in a particular network condition. In Figure 12 an example of the benefit of updating is shown. In configuration

[5] DSO perimeter is defined as a portion of the distribution grid, which can include one or more distribution grid elements (e.g. secondary substation, medium voltage electric backbone)

[6] For each POD connected to the grid, the utilization factor can be evaluated as the ratio between the effective required power and the nominal installed power.

a), and considering for simplicity only downward services, $P1_{DSO}$ represents a general DSO perimeter on which dynamic grid constraints are expressed. In the specified grid situation, where it is estimated that a certain amount of power (+4) is flowing in medium voltage towards the secondary substations (SS_1 and SS_2), if the possibility to modify the perimeter is not considered, the DSO would need to communicate a TL relative to the bottleneck of the overall perimeter, which in this case is SS_1 where the maximum capacity available is 3 and the already occupied *'space'* is 2. Leaving the possibility to update DSO perimeters, and so looking at configuration b), a different value of capability can be given concerning $P1^*_{DSO}$ and $P2^*_{DSO}$ resulting in a total increase of available flexibility for TSO planning.

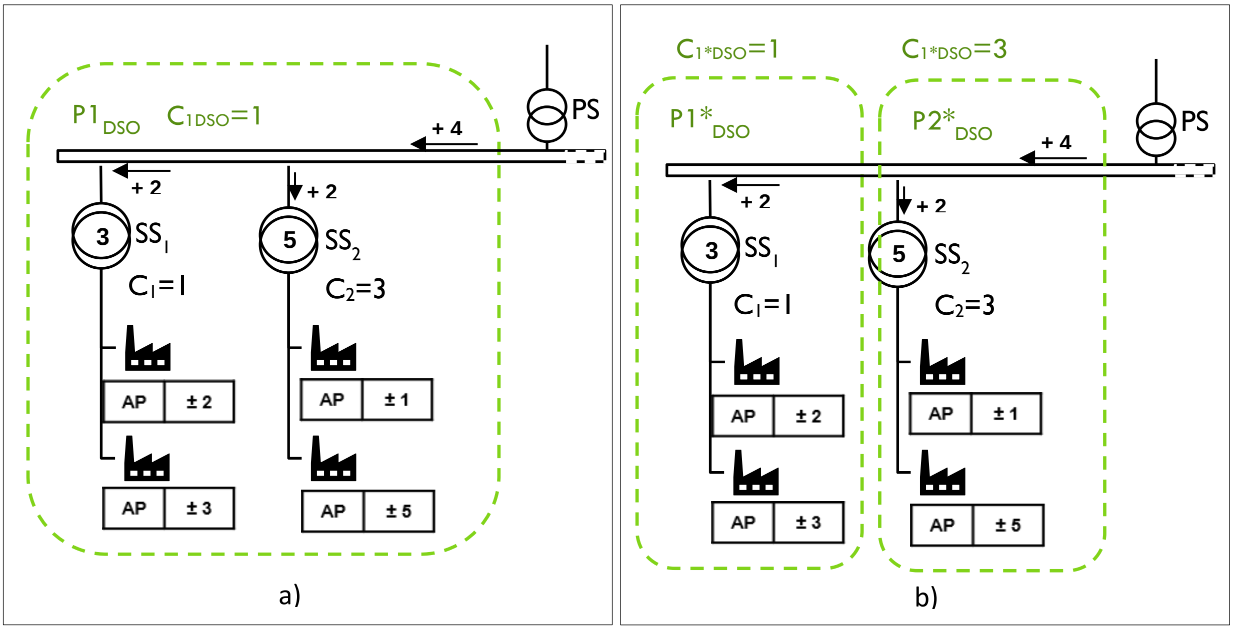


Figure 12 – Benefits of updating DSO perimeter (SS: secondary substation, PS: primary substation, AP: adjustable power, C: available capability, '→': power flow)

To summarize the coordination procedure, which is defined by a continuous information exchange, a schematic (Figure 13) and step-by-step overview is given and iteratively applied in every market session:

1. DSO performs power flows which are necessary to:
   a. plan the local flexibility needs selecting the necessary aggregates of DERs qualified to procure local flexibility services;
   b. set and/ or update the dynamic grid constraints;
2. DSO informs TSO about:
   a. The DERs Aggregates planned for local flexibility services
   b. Dynamic Traffic Light

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3. TSO plan the global flexibility activation:
    a. Taking into consideration Dynamic Traffic Light;
    b. Double-checking that SPs are not offering the amount of flexibility selected in previous markets;
4. TSO informs SP of the planned global flexibility activations;
5. SP is responsible of declaring unavailable the already selected flexibility in following planning session updating the relative market offers in the following market sessions.
6. Process starts from point 1).

As stated above, DSO informs TSO about LFM planned activations and DTL. Definition of an ex-ante programme for local resource activations in D and DTL are strictly related in fact, due to the principle of mutual unavailability and in order to prevent the creation of system counter-modulations at DSO level, it has been established that:

1. the DSO perimeter involved is constrained (red DTL) in the opposite direction to that of the local service;
2. Capability in the concordant direction of local service takes into account the maximum volume that avoids the occurrence of problems not considered by the DSO.

Referring to the example in Figure 14, assuming consumption only DERs, DSO plans the activation of the aggregates in reduction of consumption in order to secure the expected contingency. During the same delivery period, to prevent counter-modulation from TSO activation, the DTL is set red in the opposite direction (increase consumption) and yellow/green in the concordant direction (reduce consumption). Thanks to this information any subsequent activation by the TSO cannot cause problems for the DSO's network. In this context the DTL factorises the two elements reported above: network status (colour and capability concerning each DSO Perimeter) and LFP activation planning.

From the TSO perspective, service procurement on MSD will take into account the total scheduled energy at the TSO-DSO exchange point and may consider it with a sign (-/+) depending on whether or not it agrees with the direction of the required service requirement, a useful example is shown in Figure 15 to clarify the implications of the market coordination design outlined in this section. The example refers to the impact that the sum of local market activations with a sign (-/+) has with respect to the global market area. In fact, this sum could be non-zero and this implies that two scenarios can occur on the MSD procurement: the procured quantity on LFM is concordant with the TSO need and so the TSO can reduce the procurement on MSD; otherwise the procured quantity on LFM is discordant with the TSO need and so the TSO has to increase the procurement on MSD. In this second scenario, any extra energy to compensate the delta at the TSO-DSO exchange point due to the LFM is accepted as system inefficiency.

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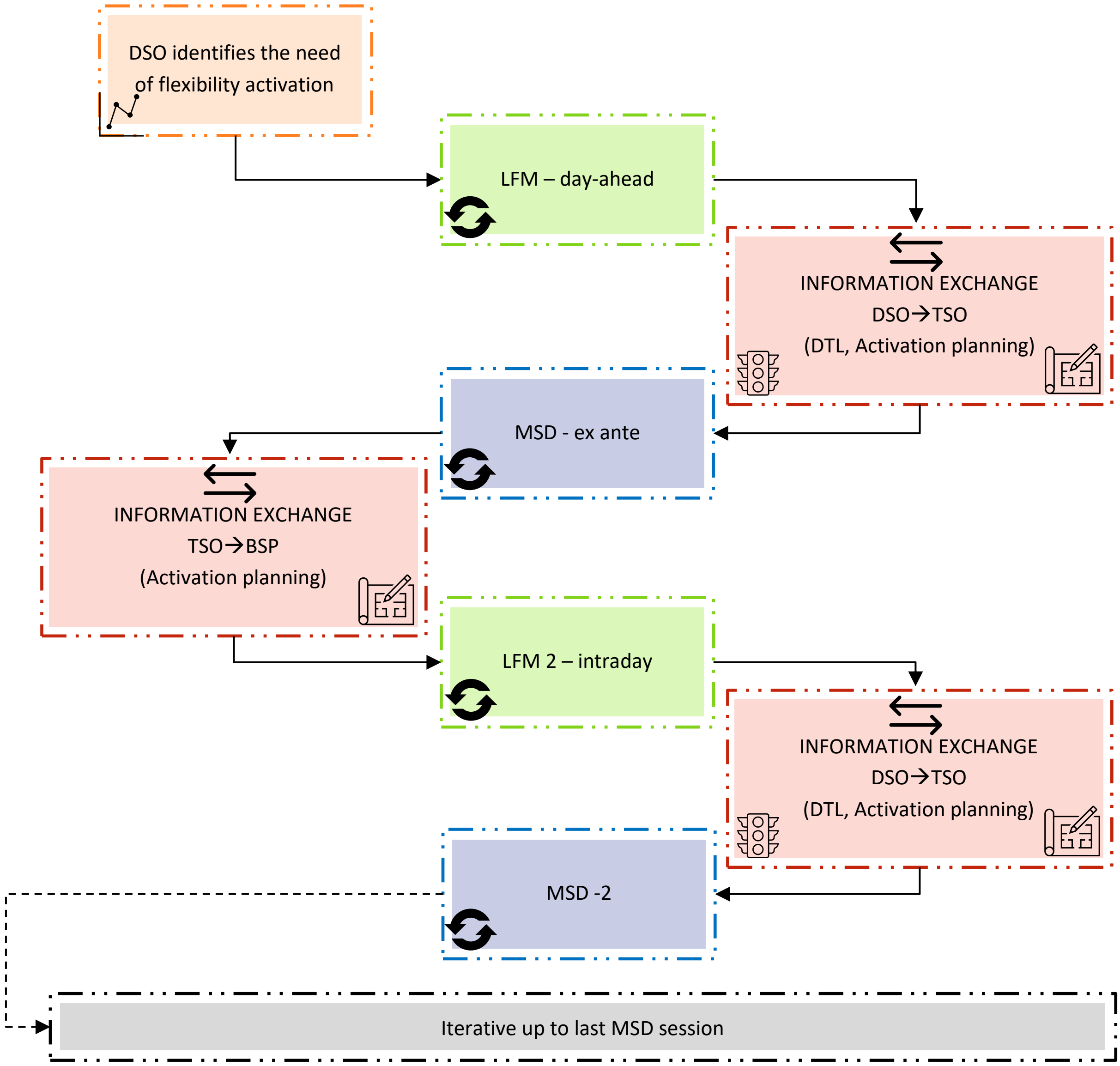

Figure 13 – Flow diagram of TSO-DSO coordination

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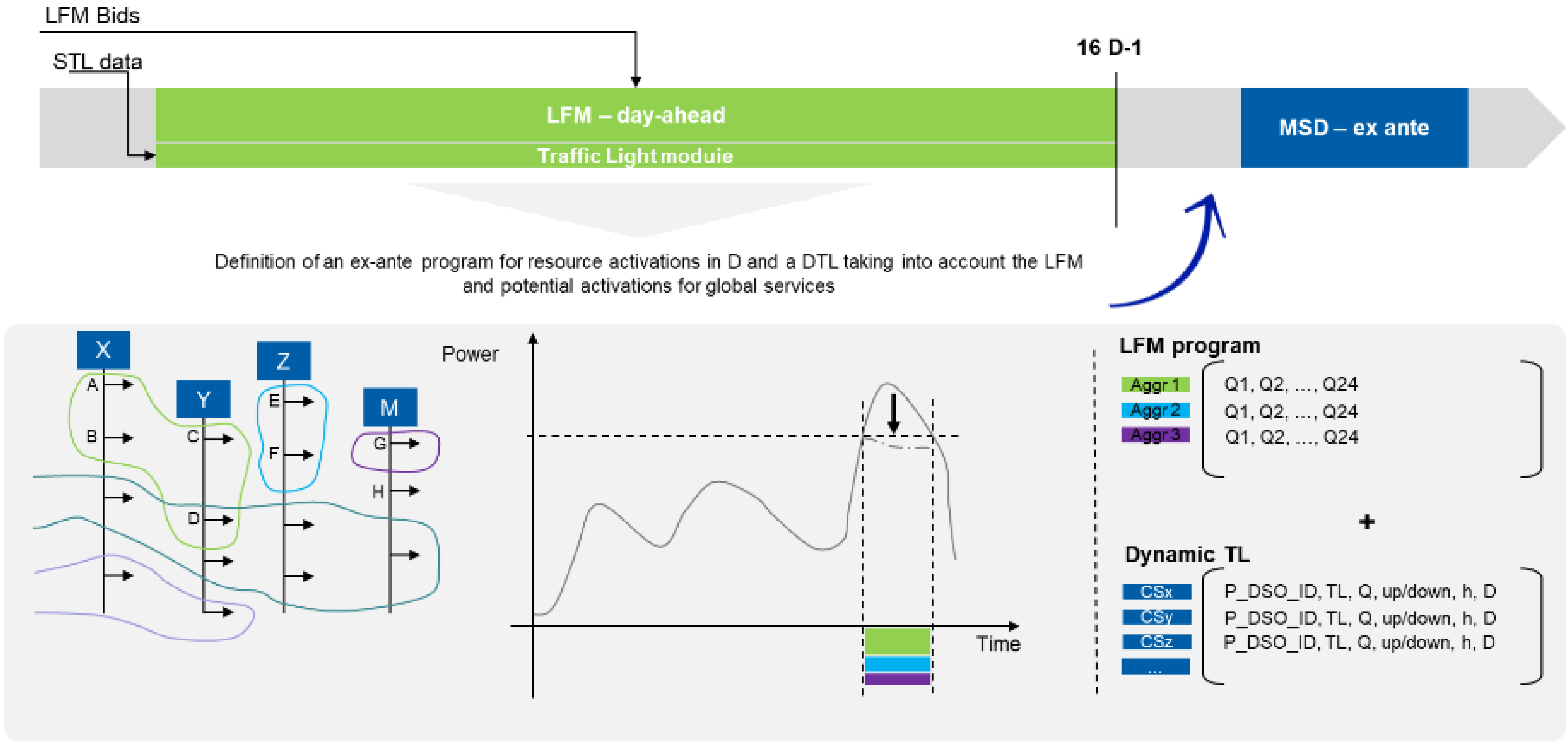

Figure 14 – Example of traffic light evaluation

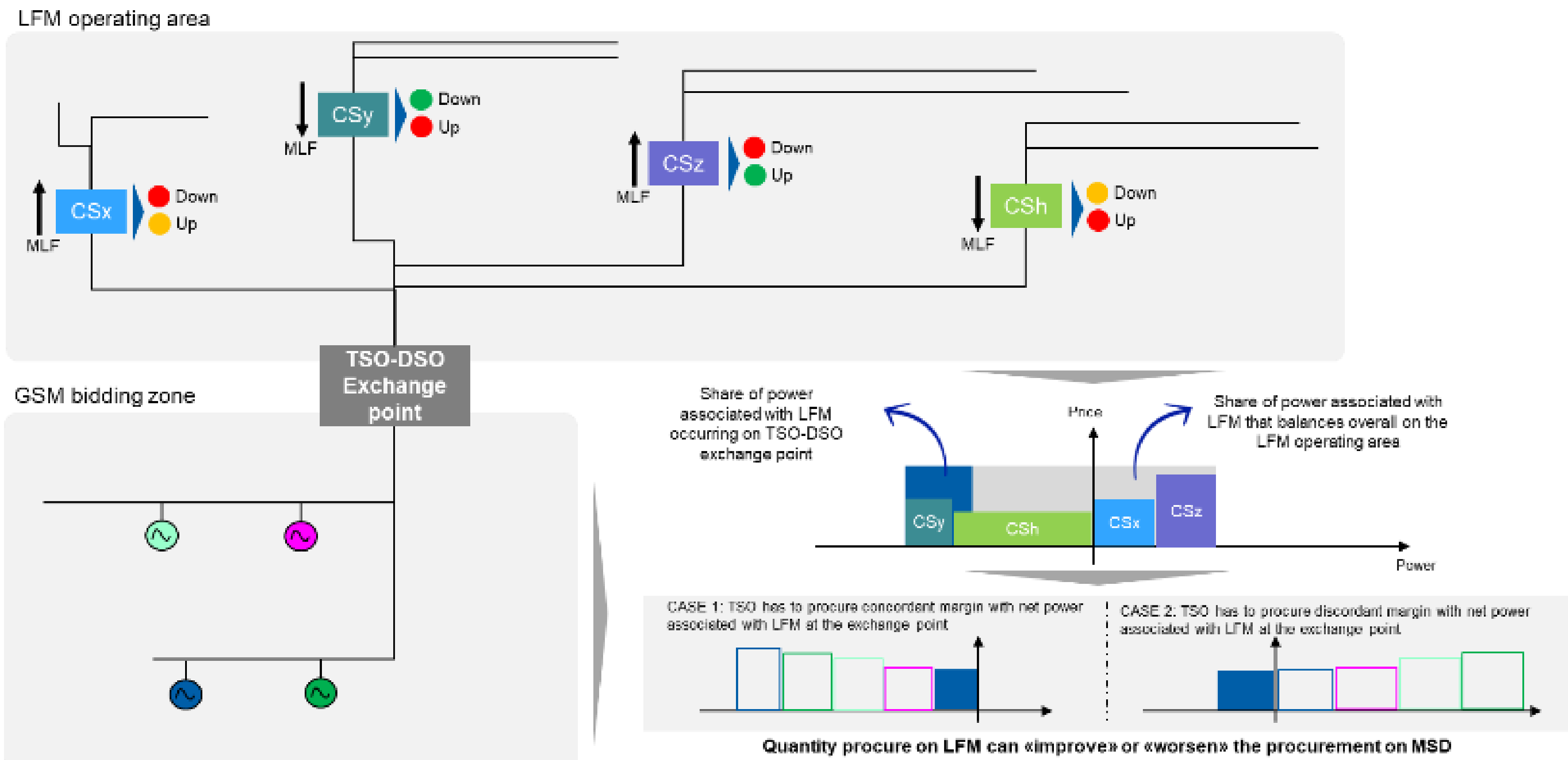

Figure 15 – Examples of configuration in global and local market coordination

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6.4. Monitoring, Activation and Settlement

Monitoring, activation and settlement phases are directly linked one to the other. In particular, the settlement is a function of the monitoring and activation phase and evaluate possible imbalances with respect to the activation setpoints. Due to the fact that TSO-DSO coordination only concerns market planning, real-time operation is handled autonomously by the respective SO, and thanks to the definition of a mutual unavailability principle and the use of sequential markets, settlement between TSO and DSO can be processed separately given that each POD can offer services for one system operator in the same delivery period. Thus, no further coordination is required in the Italian DEMO.

7. Description of platforms and tools

The architecture of the Italian fast-track demo uses different platforms and tools which continuously communicate to facilitate and create a completely integrated framework. In Figure 16 an overview of the different tools and platforms is given, then each section describes in more details each mentioned tool.

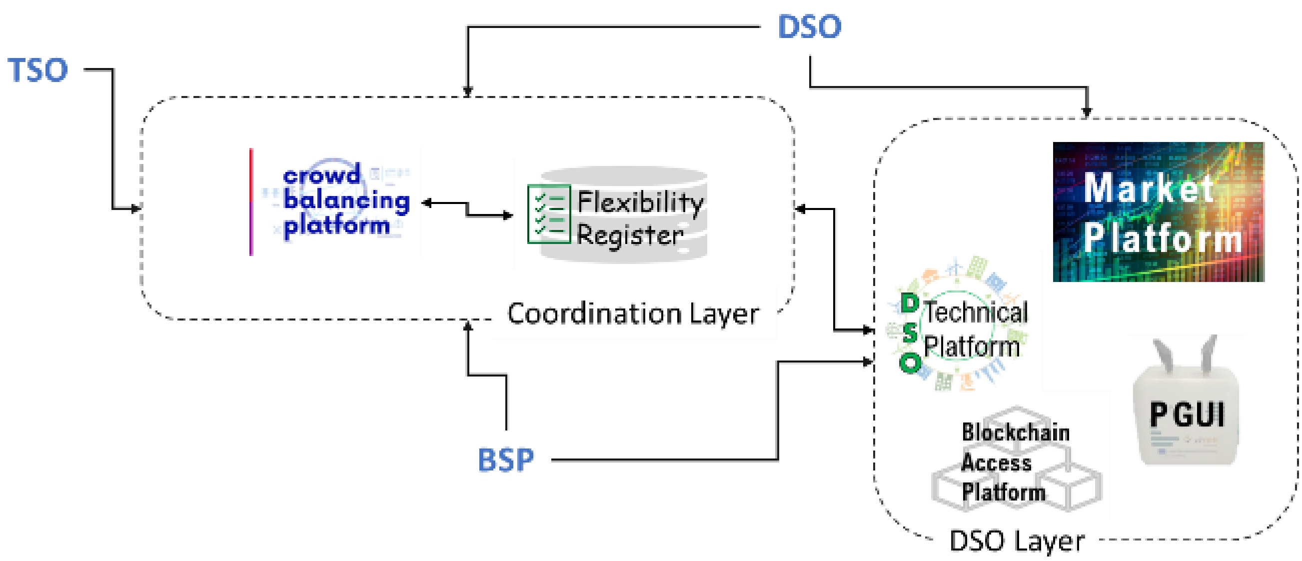

Figure 16 – Overview of tools and platform architecture

7.1. Crowd Balancing Platform (CBP)

The CBP (Crowd Balancing Platform) is the main technological tool entitled to manage all distributed data exchanges taking place within the coordination mechanism. CBP is developed by Equigy, a joint venture participated by Terna, Tennet and Swissgrid, APG, Transnet BW, with the aim of developing a platform to facilitate the participation of small distributed resources to the energy markets. As shown in **Figure 17**, the CBP constitutes the central technological layer of the system, creating a frontend which coordinates the proprietary back-end systems of the different actors (TSO, DSOs and BSPs). The CBP can include the functionalities of data registry, market operation and stakeholders interaction, which can be operated as modules within the platform.

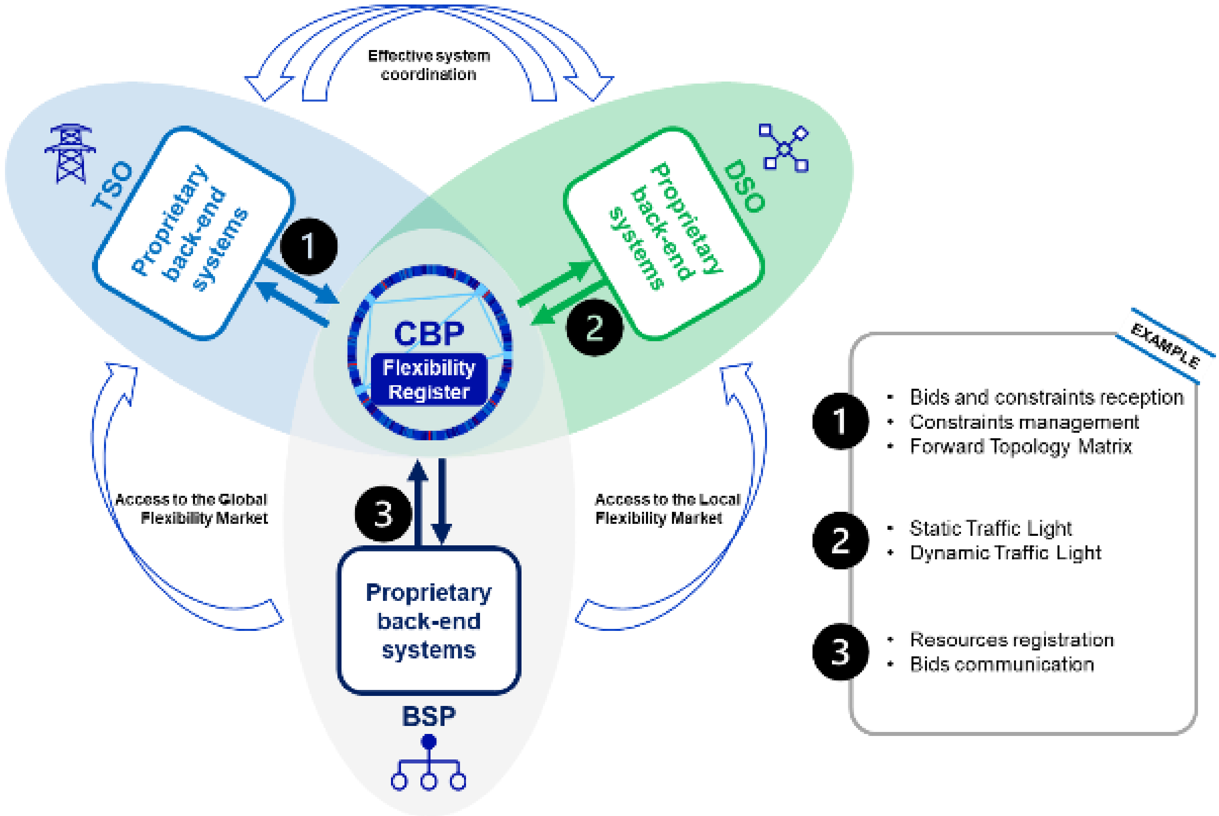

Figure 17 – CBP and its integration with other systems

The platform connects with users of its nodes through appropriate API leaving to the users' systems the operation of their business. Participants interact with CBP using APIs that are connected to the dedicated blockchain node. There is no intermediation from TSO in the information exchange: BSP and DSO directly interact with the CBP through the available APIs. In this way the CBP represents the coordination and orchestration layer between all the stakeholders involved in the process and acts as single-entry point to centrally collects all relevant data from every user.

As a single entry point, the CBP orchestrates all the information to be shared between the back-end systems of the actors and has all the functionalities that are necessary to manage the distributed data exchange that enables the coordination process across markets and the flexibility value chain stakeholders. Therefore, CBP plays a central role in the registration, validation and pre-qualification of resources, managing in an integrated way the exchanges of information between the proprietary systems of the DSO of the SP and those of the TSO in order to harmonize the process of enabling the participation of small distributed resources to the energy markets and the creation of a coherent registry among the various backends.

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Moreover, CBP is the platform through which DTL-related information, useful for market phases, can be exchanged.

7.2. Flexibility Register (FR)

The Flexibility Register is a repository system where all data related to flexible POD are stored and made available to demo platforms and stakeholders.

Data are organized according to predefined schemes and can be read by authorized platforms and stakeholders followed by authentication procedures. Data updating is allowed, after authentication, only for some types of data: for example, POD Baseline for day after can be updated by the Aggregator, while Market Outcomes cannot.

7.3. DSO Technical Platform (DSOTP)

Pilot 1.1 - Areti [11]

The DSO Technical Platform allows DSOs to improve reliability and quality of service by exploiting the flexibility made available from DERs connected to their grids. Moreover, the Platform, through interactions with Market Platform, is able to avoid activation of flexibility offers requested by TSO that could cause issues in the operated distribution grid.

More in detail, the Platform, performing forecasting of state estimation of the distribution grid, is able to predict grid congestions and voltage violations, define flexibility requests to solve the forecasted issues and verify that all market outcomes, including the ones related to TSO requests, are in compliance with grid constraints.

To perform state estimation forecast and define flexibility requests, the Platform uses several grid data and measurements coming from DSO's Operational Systems, such as Supervisory Control and Data Acquisition (SCADA) and Geo Information System (GIS) and data of flexible DERs from the Shared Customer Database. Once the grid issue is forecasted, the Platform forwards the flexible request automatically defined by the Platform, to the Market Platform.

Finally, the Platform deals to carry to each POD the flexibility services activation setpoint defined by Aggregator Platform.

Pilots 1.2 and 1.3 - E-distribuzione [10]

The Enel DSO platform enables the utilization of the flexibility provided by Distributed Energy Resources (DERs) connected to their grids. For that purpose, the platform determines the most cost-effective activation planning of flexibility services that can attend to specific grid needs, considering market constraints. Once

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the activation planning is confirmed, the platform reports it through involved agents such as service providers or market operators.

Moreover, the platform utilizes load forecasting and performs load flow calculations to predict grid criticalities such as congestion or voltage violations.

To perform all calculations, the platform is able also to gather data originally managed by other solutions and it can be also connected to a market platform.

7.4. PGUI and Blockchain Access Platform

The Blockchain Access Platform and the PGUI form the Access Layer, a data exchange infrastructure among flexible DERs, platforms and stakeholders within demo architecture.

The PGUI is a device, installed at DERs' premises, able to gather POD metering data from Low Voltage (LV) and Medium Voltage (MV) meters, receives Setpoint from DSO Technical Platform and could make it available to Customers Activation Systems such as Energy Management System (EMS), smart appliance etc. to activate flexibility.

The PGUI certifies "from the original source" (POD of the flexible DER) all managed data and sends, through the Blockchain Access Layer, to the FR.

The Blockchain Access Layer then connects the PGUI to the FR ensuring, through timestamping features, the immutability of data along the whole path.

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8. Expected benefits to the different stakeholders

Coordination between TSO and DSO is highlighted in EU regulation 2019/943 art. 57 [13], according to which an effective cooperation between TSO and DSO must rule during planning and management of their grids. This necessity is directly connected to the *Clean Energy Package*[7] of the European Union; a legislative package where EU sets the basis for a climate and energy framework for 2030 focusing on decarbonization, evolution of energy markets and energy security; and in the context of the *Fit for 55*[8] package; where Member States are responsible to achieve 55% reduction of greenhouse gas emission by 2030. Powered by these EU packages, the transition from polluting centralized generation to not programmable clean distributed generation is ongoing and, inevitably, network congestion both on transmission and distribution grid are increasing due to unpredictability of resources. Furthermore, the continuous increase of electricity consumption is pushing towards a more flexible network where consumers become active participants to network security processes. In this regard, participation of the final users to flexibility services is clearly addressed by EU directive 2019/944 on common rules for the internal market for electricity [14]:

> *(10)* ***Consumers have an essential role*** *to play in achieving the flexibility necessary to adapt the electricity system to variable and distributed renewable electricity generation. Technological progress in grid management and the generation of renewable electricity has unlocked many opportunities for consumers. Healthy competition in retail markets is essential to ensuring the market-driven deployment of innovative new services that address consumers' changing needs and abilities, while increasing system flexibility. […] By empowering consumers and providing them with the tools to participate more in the energy market, including participating in new ways, it is intended that citizens in the Union benefit from the internal market for electricity and that the Union's renewable energy targets are attained.*

This Directive should be read together with Regulation (EU) 2019/943, which lays down the key principles of the **new market design for electricity which will enable better rewards for flexibility**, provide adequate price signals, and ensure the development of functioning integrated short-term markets.

The transformation of distribution grids towards active networks with bidirectional power flow assigns a crucial role to the interaction between TSO and DSO and to the coordination of global and local market for flexibility procurement. It is important to efficiently exploit flexibility resources for both transmission and distribution grid purposes, as also suggested in regulations. Furthermore, coordination mechanisms should guarantee potential benefits for every involved stakeholder in order to be attractive. For instance, on one hand, expected benefits for TSOs are represented by a higher balancing market liquidity because of the increased number of resources, which, moreover, are expected to be cheaper than fossil fuel plants. On the

[7] Clean energy for all Europeans package
[8] Fit for 55

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other hand, DSOs could reduce network reinforcements and have a more accurate control of the grid using flexibility services to control peak power flows. Often respective needs of DSO and TSO can be discordant;thus a well-designed coordination mechanism should be able to maximize as much as possible the different necessities.

In few words, exploitation of flexibility from distributed energy resources has manifold objectives, also summarized in **Table *10***:

- Support the decarbonization of the energy system: overcoming the *Fit&Forget* approach, allows more RES-based generators to be connected to the network
- Reduce the cost for dispatching (*uplift*): the enlargement of the number of (potential) participants may result in the reduction of prices on the ancillary service market
- Reduce the grid component of electricity bill: according to Directive 2019/944, "*the network development plan shall also include the use of demand response, energy efficiency, energy storage facilities or other resources that the distribution system operator is to use as an alternative to system expansion*".

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Table 10 – Summary of expected benefits from the utilization of flexibility from distributed energy resources ([15], [16], [17], [18])

Stakeholder	Expected benefits from flexibility
Consumers/Prosumers	Reduction of energy costs: • Direct revenue from participation to flexibility markets (possibility to have an economic perspective) • Indirect: reduction of tariff components (uplift, grid costs)
Distribution System Operators	• Alternative for grid planning in security of supply management • Deferral of infrastructure investments
Transmission System Operators	• Increased ancillary services market liquidity
Government and regulators	• Support in reaching decarbonization targets • Reduction of renewable energy curtailment • The deployment of distributed resources can stimulate local job creation, especially in the renewable energy sector (e.g. local stakeholders/ aggregators could take responsibility and manage their own area/resources) • Economic growth by fostering innovation and investment in new technologies, revitalization opportunities for smaller/remote towns

9. Schedule of demo activities

The objective of the DEMO implementation is to test the coordinated qualification, acquisition/selection, activation, and validation of local and global flexibility services, with the involvement of all the necessary stakeholders (DSO, TSO, aggregators etc.). To this aim a flexibility market architecture and the coordination scheme between TSO and DSO have been proposed, starting from local flexibility services framework under demonstration in the National projects on local flexibility services. As stated above, The DEMO operates as a layer for the coordination, integration and improvement of the national pilot projects which are the main container of the experimentation. All the experimentation specific to the respective national pilots is carried out within themselves outside of this DEMO. The DEMO can integrate and test only those processes which are not foreseen in the national pilots themselves.

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9.1. Schedule of demo activities

In the following tables, the simplified Gantt charts for each Pilot is summarized. In some BUC, a colour gradient was assigned. This intends to depict a monthly overlap concerning the ending of more than one of the three implementation stages.

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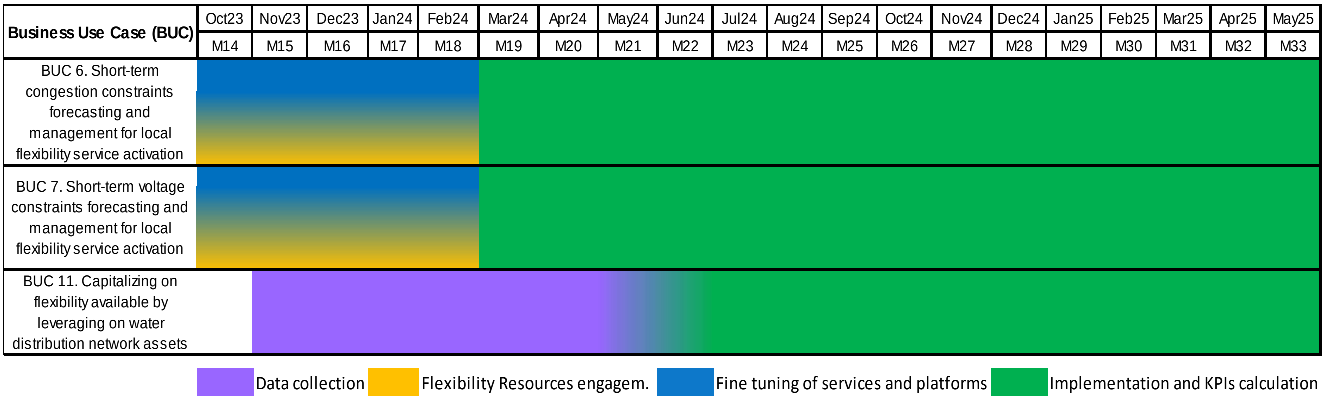
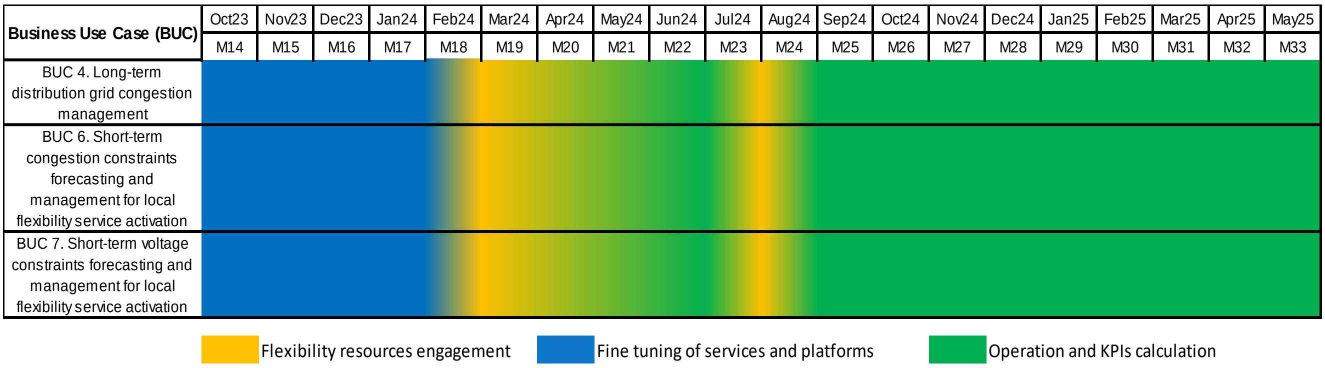
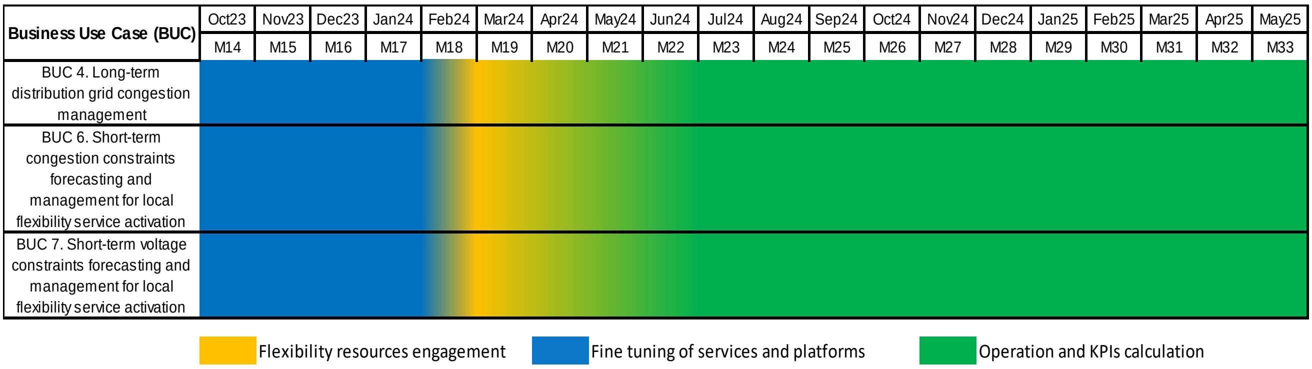
Pilot 1.1 – Rome



Pilot 1.2 – Benevento and Foggia



Pilot 1.3 – Cuneo



Pilot 1.1 Rome, Pilot 1.2 Foggia & Benevento and Pilot 1.3 Cuneo

Business Use Case (BUC)	Oct23	Nov23	Dec23	Jan24	Feb24	Mar24	Apr24	May24	Jun24	Jul24	Aug24	Sep24	Oct24	Nov24	Dec24	Jan25	Feb25	Mar25	Apr25	May25
	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33
BUC 8. Crowd Balancing: Interoperable data exchange between power system stakeholders																				
BUC 9. Local and global market coordination for distributed resources flexibility																				
BUC 10. Dynamic constraints management for global flexibility activation in transmission system operation																				

Flexibility resources engagement | Fine tuning of services and platforms | Operation and KPIs calculation

9.2. Key Performance Indicators (KPIs)

Different KPIs are defined to evaluate the quality of the proposed solution from the operational and technical perspective. They can be classified in two main groups characterized by different macro-goals:

- Analyse the exploitation of flexibility resources in planning and operational activities: ability to engage potential providers to satisfy the system needs in both TSO and DSO markets, inducing them in providing both global and local services.
- Evaluate TSO-DSO cooperation to efficiently manage shared resources and to coordinate local and global markets: ensure a cost-efficient, secure and reliable operation of their network, analysing the possibility for BSPs to offer global and local services.

The extraction of KPI listed in Table 11 comes from the cooperation with WP1 where the different Business Use Cases have been defined. As mentioned before, this activity will continue after the release of this deliverable, according to the scheduling of WP1 tasks – therefore, some definitions could be updated in a later stage, while the calculation methodology will be defined during the progress of the demonstration activity. It's worth to underline that this is a preliminary list of indicators: besides their final definition within WP1, the possibility to use them and therefore their effective calculation will depend also on which services could be actually implemented in the real field, and which processes could be simulated only due to limitations of the demo implementation and links to national regulatory pilot projects. The preliminary list of indicators is to be considered as representing an ideal coordination process which contains also the procurement of services and not only the market coordination layer which ultimately is the focus of the DEMO.

It is important to underline that the proposed KPI focus on the evaluation of the designated coordination mechanism, thus it will be observed that not all BUC cases of interest mentioned in Section 4.1 will be associated with a KPI. For example, BUC 11 focuses on distribution network, thus no KPIs are identified. Furthermore, it is important to specify that only KPIs referring to resources/processes dedicated specifically to BeFlexible project can be calculated.

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Table 11 – Key Performance Indicators adapted to the Italian fast track DEMO

KPI name	Reference BUC	Type (technical, social, grid)	Definition of the KPI
Efficiency of prequalification process in coordinated markets	BUC 09	Technical – Social	Average bureaucracy time and/or average number of technical tests performed by TSO and DSO to qualify the (aggregates of) DER with respect to the number of services provided by the (aggregates of) DER to both TSO and DSO. **Technical meaning:** Reduce the technical tests to be performed over candidate flexibilities. **Social meaning:** Facilitated access to multiple markets. **Connection to BUC KPIs** • BUC 09 (Number of prequalified customers) • BUC 09 (Number of information exchange between local and TSO markets) **Connection to KPIs proposed by the Project Grant Agreement** Positive KPI values indicates lower effort for both network operator and BSP in prequalifying flexibility. • % of potential service providers using pre-qualification platform
Impact of local constraints on DER providing global services	BUC 08 – BUC 10	Technical	Amount of flexible power that can be reliably delivered from DERs to provide global services, with respect to their total potential. Evaluate the hosting capacity of the distribution network for DERs providing global services. KPI improvements can be expected in case of: • Effective and functional TSO-DSO coordination scheme • Local markets aimed at maximising global market participation **Connection to BUC KPIs** • BUC 10 (Resource activation cost increase due to limitations)

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KPI name	Reference BUC	Type (technical, social, grid)	Definition of the KPI
Coordinated market efficiency	BUC 09	Technical	The decoupled nature of local and global markets leads to inefficiencies when they manage shared (aggregates of) DERs. This KPI measures how the TSO-DSO coordination improves the total cost of activated flexibility with respect to the ideal situation (fully coupled market).
Continuance of adoption	-	Social	**From Project Grant Agreement**: It measures the level of engagement and active participation of customers (probability that involved BSP will continue to participate to the considered markets). The increased profitability (for BSP) of flexibility markets is expected to have a positive impact on the willingness of (aggregates of) DERs in continuing to provide services even after the DEMO experimentation.

During the progress of experimental activities, the pilots will be organized in order to return easily the identified KPIs since the **preparation** phases. During the **operation** phase, each pilot will be constantly monitored to evaluate the best calculation procedure and the returned values. In case of deviation with respect to expected results, the tools and activities implemented within the demos will be promptly adapted to match the desired performance and/or justify the differences.

The temporal trends of KPIs as well as the corrective actions taken by network operators to enhance the performance of the tested use case will be documented during the **assessment** phase. Network operators have also the role of keeping tracks of both good and bad practices in order to draft an exhaustive list of lesson learned from the demonstration activities.

According to the current expectation, the TSO-DSO coordination will not be easily tested on the real field due to limitations in available flexibility resources dedicated to the DEMO. A simulation environment will be set up in order to evaluate the benefits of the market coordination by feeding the model with real data (possibly from the field), with the aim of obtaining KPIs results which are representative of a realistic situation.

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10. Conclusion

In this document the conceptual framework for an efficient management and operation of the pilots within the fast track DEMO1 is proposed. This framework has been defined thanks to the close cooperation of the WP4 partners, in M1-M14 of the Project, and it will be likely updated in the later stages, for two main reasons: *firstly*, DEMO1 relies on National projects on the traffic light mechanism and on local flexibility services, that will be fully deployed starting from 2024. *Secondly*, at M14 (October 2023) of the BeFlexible project, the discussions on Business Use Cases (BUCs), System Use Cases (SUCs), and on Key Performance Indicators (KPIs), are still ongoing in the relevant Tasks and some adjustments could be further applied.

After a comprehensive review of past EU projects on the topic of coordination between TSO and DSO for the flexibility services, the first activity carried out in T4.1 dealt with the mapping and characterization of testing scenarios/use cases in the different pilot areas, which differ in the type of territory served (urban, rural) and the flexibility resources that could be involved. The selected BUCs focus mainly on the *coordination* between grid operators. In general, DEMO activities will focus on processes which are additional to those valid at national level.

Then, a deep discussion was carried out on the coordinated process of resource procurement: the model has been designed starting from the so-called *multi-level market model* given in the CoordiNet project. It considers two separate buyers of flexibility (TSO and DSO), and different market-based frameworks to procure flexibility. The description of the process was then divided into steps: registration and pre-qualification, market and planning phase, real time activation, and settlement.

With respect to the above framework, platforms and tools in DEMO1 were described – namely the Crowd Balancing Platform (CBP), the Flexibility Register (FR), the DSO technical platform(s), and the utilization of blockchain technologies. In this document, objectives and mutual interactions between those platforms are depicted, while the implementation details will be given in task T4.2.

The demonstration plan was then outlined, considering the activities related to the objective of the Project: engagement of flexibility resources, fine tuning of services and platforms, operation and KPIs. As mentioned before, with respect to the *coordination* the interactions between actors and systems will be simulated. Different KPIs were defined, in coordination with the ongoing activities in Task T3.1, in order to assess two different macro-goals: analyze the exploitation of flexibility resources in planning and operational activities, and evaluate the TSO-DSO cooperation. As mentioned before, this activity will continue after the release of this deliverable, according to the scheduling of WP1 tasks – therefore, some definitions or calculation methodologies could be updated in a later stage.

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