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WP4 – Smart Grids Framework for an Interoperable Energy System

D4.1

Functional Specification of DSO Standard Interface Application

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AUTHOR (S)	Clara Gouveia (INESC TEC) Fábio Coelho (INESC TEC) José Villar (INESC TEC) Alexandre Lucas (INESC TEC) Maren Fiege (EEBUS) Joost Laarakkers (TNO) Kristian Helmholt (TNO) Chris Caerts (VITO) Janka Vanschoenwinkel (VITO) Bernardo Almeida (E-REDES) Carlos Cândido (E-REDES) João Falcão (E-REDES) Uršula Krisper (ELJ) Olivier Genest (TRIALOG) Amélie Gyrard (TRIALOG) Hadrien Lafforgue (TRIALOG) Dune Sebilleau (TRIALOG) Mojtaba Eliassi (3E) Matthieu Rubion (Enedis) Romain Bonnin (Enedis) Oussama DAOR (Enedis) Kevin Loussouarn (Enedis) Cami Dodge-Lamm (CYB) Kirsten Glennung (EDSO)
OFFICIAL REVIEWER/s	E-REDES

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DISCLAIMER:

History of changes

Deliverable 4.1 has suffered two main revisions. Table below summarizes the main changes performed.

Document Version	Date of Submission	Description of changes
First submission	07/05/2021	Original version submitted

First revision	30/09/2021	The following changes were conducted in response to technical reviewers' comments:
		• More complete executive summary was added to highlight the DSO Interface concept, innovation and development path
		• Chapter 2 and 3 were revised in order to present more clearly the basis for the DSO Interface architecture and service identification. This chapter provide clear outputs to the DSO Interface specification, namely:
		  ○ Focus on the flexibility mechanisms and processes relevant to the project
		  ○ Identification of other platform features relevant for the DSO Interface architecture and services
		• Chapter 4 was revised adding to the conceptual architecture of the DSO Interface the identification of the functional modules (see Table 16 and Figure 28 and 29).
		• Chapter 4 and Chapter 5 were revised considering a clearer matching between DSO Interface services and data exchange.
		• A clear identification of applicable information models and standards was included in Chapter 5 (section 5.3 and 5.4) as well as gap analysis.

Second revision	31/01/2022	The following changes were conducted in response to technical reviewers' comments, to clarify the market platform interaction of the DSO Interface. Two main changes are highlighted: • In Chapter 4, in addition to the identification and characterization of the functional modules of the DSO Interface, sub-section was added to detail the approach followed in InterConnect for market-based flexibility procurement. As seen in most pilots for flexibility procurement at the distribution level, InterConnect has considered that flexibility procurement is managed by the DSO. Therefore, DSO Interface integrates the Flexibility Management Platform responsible for managing the flexibility procurement processes between DSO legacy systems and Aggregation Platforms and consumers. This is now clarified in section 4.2.1. • In Chapter 5, the steps that are being followed in Task 4.2 and Task 4.3 towards sarefization of services are explained in addition to the gap analysis of standards and information models for DSO services data exchanged. • Executive summary revised to reflect the main changes performed in the document.

EXECUTIVE SUMMARY

What is this deliverable about?

The main objective of this deliverable is to specify within InterConnect ecosystem the DSO Interface, a fully interoperable and replicable interface to ensure neutral, transparent, and secure data access to all market players.

The deliverable provides the functional specification of InterConnect DSO standard interface, defining its reference architecture and interoperability guidelines to enable the seamless implementation of implicit and market-based flexibility mechanisms technology and increase the value of DSO and consumers data.

One of the key features of this interface is its replicability to different European countries and its interoperability. Therefore, the DSO Interface architecture was developed based on the following rationale:

1. Identification of the most relevant flexibility relevant mechanisms and services, as presented in Chapter 2, taking as input the grid services identified in Deliverable 1.1 [69].
2. Leverage from the main characteristics, services and data models adopted in similar platforms developed in EU H2020 projects, as presented in Chapter 3.
3. Enable InterConnect use cases and services (energy and non-energy) involving interaction with the DSO. The first step in DSO Interface definition was the identification of relevant InterConnect use cases, to map the interactions and data exchange from the DSO and other relevant actors. The related use cases are identified in Table 1 and input to the high-level specification in Chapter 4.
4. The interface specification aims at fostering replicability and interoperability through semantical concepts and existing standards and information models that are already established as the most probable standard for TSO and DSO domains and direct interactions (energy and local markets). Chapter 5 identifies and characterizes relevant information models to implement DSO Interface services.

What is the DSO Interface and how it fits in Interconnect Interoperability Framework?

The DSO interface concept was developed as part of Interconnects smart energy reference architecture [71], to ensure a standard interaction between DSOs and energy and non-energy marketplaces, ensuring neutral, transparent and secure data access to all market players.

The DSO interface will enable the demonstration of InterConnect use cases adopting a standard and replicable interface with the DSOs from the different pilots, in order to:

- Allow universal access of DER, microgrids and energy communities in flexibility and energy markets, considering different flexibility market models (including P2P markets).
- Accommodate flexibility services designed according to the needs of the DSO
- Comply with GDPR
- Comply with cybersecurity standards and requirements

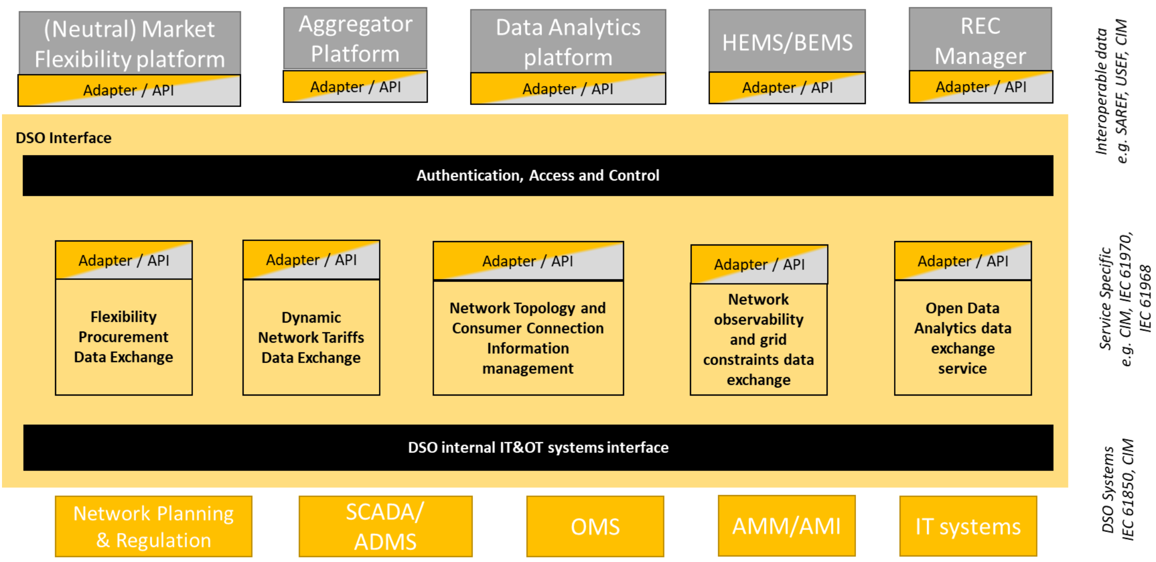
The DSO interface architecture is represented in Figure 25. It builds a gateway between DSO's legacy systems for IT&OT operation, with other relevant actors such as: Aggregators, Data Service Providers and ultimately with consumers (see Figure 23).

The DSO interface is composed of the following building blocks:

- InterConnect generic adapter(s), providing the interface between DSO's core-services (discussed in 4.2.2) and external stakeholders within Interoperability Framework (IFA). When incoming data requests arrive at the adapter, they are routed to one of the specific core service controllers available, that then bridge with the DSOs OT systems.
- DSO Interface data exchange and management services platform, responsible for the data management, aggregation according to the specificities of the services and also for the necessary data translations between interoperable data that arrives from the ecosystem and specific data formats e.g., CIM, IEC 61850. The same happens for the inverse scenario when data originates at the DSO interface and is forwarded to other stakeholders.
- Interface towards internal IT and OT systems and authentication and access control mechanisms.

In this deliverable is also presented the internal structure of the DSO Interface (see Figure 26) and its main modules (see Table 16). Two key components are:

- Communication Midleware managing the interactions with external actors and with DSO internal systems and will ensure connection with the InterConnect semantic interoperable layer.
- Running Services, required to implement the InterConnect use cases involving the DSO and other external actors.



DSO INTERFACE HIGH-LEVEL ARCHITECTURE.

What are the DSO Interface core services?

Leveraging from InterConnect's IFA, the DSOs developed interfaces and platforms enables and implement new services (See Table 1) that aim to:

- value smart metering data to foster local energy communities, flexibility services and cross-sector services (e.g., financing of DER projects).
- establish technology agnostic flexibility procurement processes and data exchange with aggregators or flexibility market platforms (external to the DSO).

- leverage from third-party data (e.g., behind-the-meter measurements) to improve network observability and planning, enabling new business models such as Data Brokers.

The DSO interface enables the implementation of flexibility and data-driven services to the DSO and the consumers. The five main services enabled by the interface are:

- Flexibility Procurement includes the data related with flexibility forecast and procurement foreseen in InterConnect use case (see Table 1) for the Portuguese, Greek and Belgium pilots.
- Dynamic Network Tariffs and incentive tables, enabling the exchange with the consumer and/or retailer of a dynamic tariff structure and incentive table, foreseen in the use cases German, Belgium, France and Italy use cases (see Table 1).
- Network Topology and Consumer Connection, mapping network and consumer nodes with flexibility zona/area/node from the request and mapping information from HEMS to network data (for observability purposes).
- Network Observability and Grid Constraints, enabling the services proposed in the Portuguese demo (see HLUC 11 in Table 1), where HEMS and smart meter data is used to improve outage location, assess LV network operation status considering the integration of EV, heat pumps and other relevant resources and finally assessing the adequacy of flexibility mechanisms (dynamic tariffs, incentive tables or flexibility dispatch resulting from market-based services).
- Open Data Analytics, a set of DSO services that aim at valorizing smart meter data for energy consumption awareness as well as flexibility market activities.

A first characterization of the data exchange involved in each service is identified in Chapter 4. Also, the recommendations provided in Chapter 5 will be considered for the data modelling and service development ongoing in Task 4.2 and Task 4.3. More details on the data modelling and specification of the other modules of the DSO Interface will be provided in Deliverable 4.2.

How does DSO Interface interact with Flexibility Market Platforms?

Within InterConnect use cases, the DSO assumes the role of Neutral Market Operator, being responsible for the main processes for flexibility procurement: registration & pre-qualification, forecasting, procurement or market operation, delivery and settlement procurement. The DSO will then interact directly with the aggregator for the provision of flexibility services, for solving grid technical constraints.

As explained in Chapter 4, the DSO Interface will enable procurement of flexibility provided by aggregators or directly by the consumers, ensuring the required data exchange between DSO legacy systems (CRM, ADMS, AMI) and the external flexibility providers and aggregators. Focusing mainly in the procurement process (within the scope of the project), the DSO Interface incorporates the Flexibility Management platform (Figure 26) responsible for managing all the processes and data exchanged, namely:

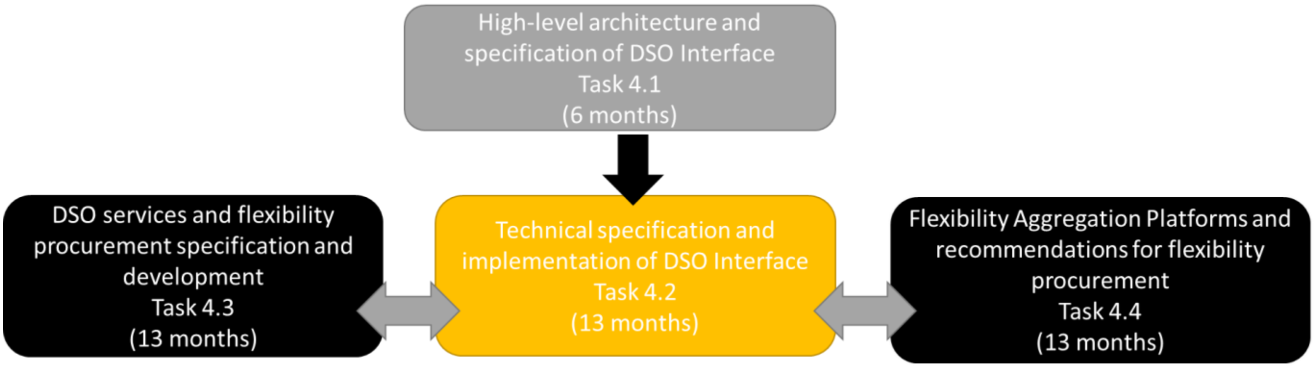
- Interact with ADMS for the gathering flexibility needs for the next day or hours.
- Formulate and publish flexibility requests, considering flexibility needs and the consumers codes eligible to provide flexibility (after registration and pre-qualification process).
- Receive, validate and check if offers are eligible and forward to DSO ADMS for selection of offers.
- Publish and activate selected flexibility offers.

- Check delivery of services and manage settlement data exchange between CRM and flexibility service providers.

The technical specification and development of the Flexibility Management Platform is foreseen in Task 4.2, as part of the DSO Interface. The development of this platform is also dependent on the work of task 4.4, where the Flexibility aggregation platform (from Cybergrid) is being designed and will be tested together with the DSO Interface in the Portuguese pilot. More details on the data exchange modelling can be found in D4.2 and D4.4.

What are the next steps in the development and deployment of DSO Interface?

This report presents the work developed under Task 4.1, which aimed at providing the high-level specification of DSO Interface, that will establish the ground for the technical specification (corresponding to Deliverable 4.2) and interface development.



DSO INTERFACE DEVELOPMENT AND TASK RELATION.

The functional specification presented in this document provides as main outputs:

- High-level architecture of the DSO Interface, compatible with InterConnect end-to-end use cases from the grid to end users, required for the technical specification and implementation of the component foreseen in Task 4.2.
- Characterization of the energy and non-energy services enabled by the DSO Interface. In addition to implicit and explicit flexibility mechanisms, the interface enables innovative services valuing DSO smart metering data and consumers data to benefit DSO monitoring and system awareness capabilities. Implementation of services is foreseen in Task 4.3 in close coordination with pilot implementation (particularly Portuguese, French and German pilots)
- Characterization of the data exchange and analyses of applicable standards information models that can help in the sarefization process, ongoing in close collaboration with WP2, WP3 and WP5.

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ABBREVIATIONS AND ACRONYMS

ADMS	Advanced Distribution Management System
AGG	Aggregator
API	Application Programming Interface
BEMS	Building Energy Management System
BRP	Balance Responsible Party
DER	Distributed Energy Resources
DG	Distributed Generation
DRA	Demand Response Aggregator
DSO	Distribution System Operator
DSP	Data Service Provider
EPEX	European Power Exchange
EV	Electric Vehicle
ESP	Energy Service Provider
FACTS	Flexible Alternating Current Transmission System
FCP	Forecast Provider
FCR	Frequency Containment Reserve
FRR	Frequency Restoration Reserve
FRT	Fault Ride Through
FSP	Flexibility Service Provider
HEMS	Home Energy Management System
HV	High Voltage
IFA	InterConnect Interoperability Framework
LV	Low Voltage
MDO	Metering Data Operator
MV	Medium Voltage
OLTC	On-Load Tap Changer
PV	Photovoltaic
P2P	Peer to peer
RES	Renewable Energy Sources
RFI	Request For Information
RR	Replacement Reserves
SAREF	Smart Applications REFerence
SGU	Significant Grid Users
SGAM	Smart Grid Architecture Model
TSO	Transmission System Operator
UFTP	USEF Flexibility Trading Protocol
USEF	Universal Smart Energy Framework
VPP	Virtual Power Plant

1. INTRODUCTION

The Distribution System Operator (DSO) plays a key role in the development of a consumer-centric energy system, enabling new standardized flexibility products provided by smart homes, buildings and communities. This deliverable provides the functional specification and architecture of the DSO Interface, which ensures a fully interoperable and replicable interface with new marketplaces and actors, enabling the implementation of InterConnect use cases.

The deliverable provides the reference architecture and interoperability guidelines, to ensure neutral, transparent, and secure data access to all market players. It is intended to enable market transactions, and at the same time, help manage the flexibility needs of the distribution networks. The DSO interface enables replicability over InterConnect pilots and interoperability with existing systems and tools from energy domain players. To this end, a collection of use cases from the different pilots was taken into consideration, in order to capture the variety of needs and approaches. At this functional stage, the compliance with GDPR is respected, following other reference platforms.

The DSO interface was specified to enable the implementation of relevant flexibility services identified that can help manage distribution and transmission grids, energy markets, while taking as inputs the grid-centric services and use cases from WP1, as well as other relevant European projects and other initiatives. These services will be exploited within InterConnect through implicit and market-based mechanisms, that will result in distinct interactions and data exchange between actors. The DSO Interface will then enable the implementation of these different mechanisms through a standardized approach, for both services, data exchange and communication, also considering the platforms demonstrated in relevant EU H2020 projects such as Interflex, Integrid, Platone and FHP.

In parallel to the realization of this deliverable, European entities bridging DSO, TSO and market actors (EDSO, Eurelectric for example) are working on a network code enabling congestion management. However, no public results are available so far. Therefore, the flexibility mechanisms described, adopted throughout this deliverable, are mainly based on the results of current European projects and pilot demonstrations.

Aiming at full interoperability within Interconnect energy ecosystem and aligned with WP2 semantic interoperability framework, a gap analysis of the applicable ontologies for the exchange of information with the DSO was conducted for the DSO Interface services. The DSO architecture and services is then derived building upon the identified services, use cases and related platforms, paving the way for the technical and more detailed specification.

1.1 DELIVERABLE D4.1 DEPENDENCIES

The functional specification of the DSO Interface described in this deliverable has the following dependencies:

- Grid-centric services, business and system use cases from WP1. The DSO Interface considers the flexibility services and use cases involving the DSO. The specification takes as key inputs the interaction between the actors and the data exchange identified in IEC62559 and SGAM diagrams.

- Interconnect smart energy reference architecture and semantic interoperability from WP2. The DSO Interface architecture is aligned with smart energy reference architecture defined in Task 2.2 and has been involved in the discussions of the semantic interoperability of Task 2.3 and 2.4, particularly in the applicability of SAREF and other ontologies and standards to the data exchanged with the DSO.
- Digital platforms and marketplace in WP5, considering the interaction with the DSO Interface, namely with the provision of non-energy services to the DSO and the flexibility energy services enabled by WP3 services. WP5 alignment was assured regarding the definition of the architecture of the interoperable marketplace toolbox.
- The output of Task 4.1 will provide the necessary information for the technical specification of DSO standard interface application tackled in T4.2.
- The results from Task 4.1 can also contribute to WP9, namely to task 9.1 in what concerns standardization efforts related with the DSO data exchange to flexibility and non-energy marketplaces.

1.2 IDENTIFICATION OF INTERCONNECT USE CASES THAT COULD TAKE ADVANTAGE OF THE DSO INTERFACE

The Interconnect use cases that involve the interaction with the DSO for the implementation of energy and non-energy services are collected in Table 1. The characterization of the interactions between use case actors and data exchanged is key for the specification of the DSO Interface architecture.

1.3 DELIVERABLE OBJECTIVES AND STRUCTURE

This deliverable provides the functional specification and architecture of the DSO Interface, which ensures a fully interoperable and replicable interface with new marketplaces and actors. The document provides a solid background support regarding, on one hand, services products and needs for flexibility provision, and on the other, identify the exchanges of information and applicable ontologies to propose a set of architectures enabling the next task of the WP, which is the technical specification. The framework described in this deliverable is adapted to the scope of InterConnect project and is most suited for a liquid flexibility market.

The document is structured as follows:

- Chapter 2 – Identification of actors and processes for flexibility, presenting the most relevant flexibility services and relevant mechanisms for its acquisition, with the main objective of characterizing the actor’s interaction and data exchanged.
- Chapter 3 – Revision of EU projects and platform interfaces, presenting its main architecture, services and data exchange schemes adopted.
- Chapter 4 – Specification of the DSO Interface, identifying the interface services, architecture and data models according to the identified standards and ontologies.
- Chapter 5 – Overview of existing ontologies, identifying those applicable to Interconnect and the existing gaps for the data exchange and communication processes.

TABLE 1 - SUMMARY OF THE USE CASES ANALYZED WITHIN THE INTERCONNECT

Demo	HLUC	Main scope of HLUC
Portugal	HLUC 5 – DSO Data Sharing 4 New Energy Services	• Dynamic contracted power limitation • Flexibility mapping (forecast or historical on flex needs) • Smart meter anonymized data for awareness and market participation
	HLUC10 – Flexibility Management for Distribution Grid Support	• Day-ahead flexibility procurement and mobilization for MV and LV grid support
	HLUC11 – Enhancing Distribution Grid Observability with end user data	• Improve distribution network observability through data analytics services considering data from HEMS and smart meters. Three main services are foreseen: - Improve fault location in MV and LV networks - Estimate elasticity of LV consumers to flexibility incentive mechanisms - Analyse LV network status and assessment of impact of specific load types
Germany	HLUC01 – Maximize utilization of renewable -wind- energy @grid connection point	• Dynamic network tariffs (Time of use tariff) • Energy Demand Forecast • Active Power limitation • Grid monitoring at connection point (energy, voltage, frequency)
	HLUC 2 – Maximize utilization of DER energy consumption in premises	
	HLUC 3 – Grid stability via power limitation at grid connection	
France	HLUC 2 – Dynamic tariff	• Dynamic tariff structure • Consumer Smart meter self-consumption mode activation • Smart Meter data management for real-time monitoring
Belgium	Cordium – HLUC 1 – Community Cost optimization – district & building level Thor Park – HLUC 1 – Thor Park. Community cost optimization	• Dynamic power limitation • Dynamic tariff structure • Flexibility Forecast • Self-consumption plan and flexibility
Italy	HLUC 1 – Digital Platform for control and awareness (PUC 4 – Time of Use Tariff)	• Dynamic energy and network tariff for incentivizing load shifting
	HLUC 1 – Digital Platform for control and awareness (PUC 3 - Exchange of aggregated flexibility data)	• Flexibility aggregation from residential users to provide ancillary services to the TSO
Greek	HLUC 3 – Flexibility Provision	• Day-ahead provision of flexibility for grid support through incentive-based demand-response

2. IDENTIFICATION OF ACTORS AND PROCESSES FOR FLEXIBILITY PROVISION

The large-scale integration of Distributed Generation (DG) based on Renewable Energy Sources (RES), increases the uncertainty in power systems operation, replacing conventional and controllable generation, and consequently reducing the inertia in the system and making it more challenging to ensure voltage and frequency regulation. This generates new system needs due to potential upcoming flexibility scarcities, increasing the complexity of operating both transmission and distribution networks. Under this context, the design principle of 'generation follows demand' must give place to more ambitious design and operation principles based on the local optimization of consumption and generation of electricity to improve the power system operation efficiency and to decrease the need for other costly flexibility measures. At the DSO, side this requires expanding its traditional roles towards a more active operation of the network, integrating Distributed Energy Resources (DER) [1] and using their available load and generation flexibility to support both TSO and DSO by means of adequate market-based coordinated mechanisms [2][3].

With a very broad approach, ISGAN [4], via reviewing several definitions presented by CIGRE, IEA, EURELECTRIC, IRENA, CEER, and EPRI, defines flexibility as "*the ability of the power system to manage changes in which the flexibility term covers, as an umbrella, all the needs and services in the power system*".

This section deals with the main actors, the regulated and commercial needs for flexibility, and some of the more relevant processes involved in the flexibility acquisition for the regulated and commercial system balancing and for an improved and more flexible operation of the power system.

In parallel to the realization of this deliverable, European entities bridging DSO, TSO and market actors (EDSO and Eurelectric for example) are working on a network code enabling congestion management. However, no public results are available so far. Therefore, the flexibility mechanisms described in this chapter are mainly based on the results of current European projects and pilot demonstrations.

2.1 IDENTIFICATION OF RELEVANT ACTORS AND ROLES

Many of the projects and initiatives that deal with flexibility acquisition define their own actor and role models (see for example [6]-[7], [10]). While actors typically refer to real entities that participate in a business model framework, roles represent external intended behaviours the actors could perform, and, as such, actors can assume one or more roles. For simplicity, this document proposes the following main actors involved in the InterConnect use cases (see Table 1), particularly focusing in the process of flexibility acquisition as shown in Figure 1.

Transmission System Operator (TSO) is a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the transmission system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the transmission of electricity (EU Directive 2019/944)

Distribution System Operator (DSO) in the European Union Internal Electricity Market is legally defined in Article 2(29) of the Directive (EU) 2019/944, as a 'natural or legal person who is responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the distribution of electricity'.

EU regulation 2017/1485 establishes a guideline on electricity transmission system operation and also provides "*rules and responsibilities for the coordination and data exchange between TSOs, between TSOs and DSOs, and between TSOs or DSOs and SGUs (significant grid users), in operational planning and in close to real-time operation*".

Balance responsible party (BRP) is defined in Regulation (EU) 2019/943 as a market participant or its chosen representative responsible for its imbalances.

Metering data operator (MDO) is and entity responsible for acquiring, storing and distributing validated measured data. Very often, this role is performed by the DSO [10].

Neutral Market Operator, neutral third parties for buyers and sellers of flexible electricity sources to register their requirements and capabilities and facilitating trading and price formation in local flexibility markets [9].

Aggregator (AGG) is a third-party company specializing in electricity demand side participation. In practice, Aggregator contracts with the individual DER and demand sites (industrial, commercial, or residential **consumers**) and aggregate them together to operate as a single DSR provider to TSO, DSO and BRP [11]. Flexibility provider or **flexibility service provider** (**FSP**) are very often alternative ways of calling the Aggregators. However, in some role models the aggregator has the role of portfolio aggregation and optimization, and the FSP is the market participant that offers the flexibility aggregated by the aggregator to the flexibility procurers, even if both roles are very often performed by the same entity. Aggregators can interact with the resources they aggregate through energy management systems (**EMS**), namely home energy management systems (**HEMS**) in the case of final consumers, or building energy management systems (**BEMS**). Under the context of collective self-consumption, local electricity markets and **renewable energy communities** (**REC**), independent aggregators could also aggregate and sell the flexibility available at the community level to BRP or system operators, or the community itself could behave as an aggregator, as Directive (EU) 2018/2001 suggests. However, how local electricity markets (P2P or more market structured organizations) can integrate flexibility provision is an open discussion and no clear proposals have yet been formulated. See Annex 2 for a revision on local electricity markets and how they relate to flexibility provision.

Energy Service provider (**ESP), Supplier** or **Retailer,** is the entity responsible of buying electricity in the wholesale market and selling it to its customers. Suppliers are in general BRP although some role models distinguish both assuming that SP role is limited to selling energy to its customers and invoicing. Suppliers (as an entity) assume very often the role of aggregators.

Data Service Provider (DSP) is an entity that provides data analytics service to the DSO such as the forecasts of RES, generation and consumption based on different data (e.g., weather data and historical load flow) to be used for grid analysis and flexibility availability computations. When providing forecasts, it can usually refer to as Forecast Service provider.

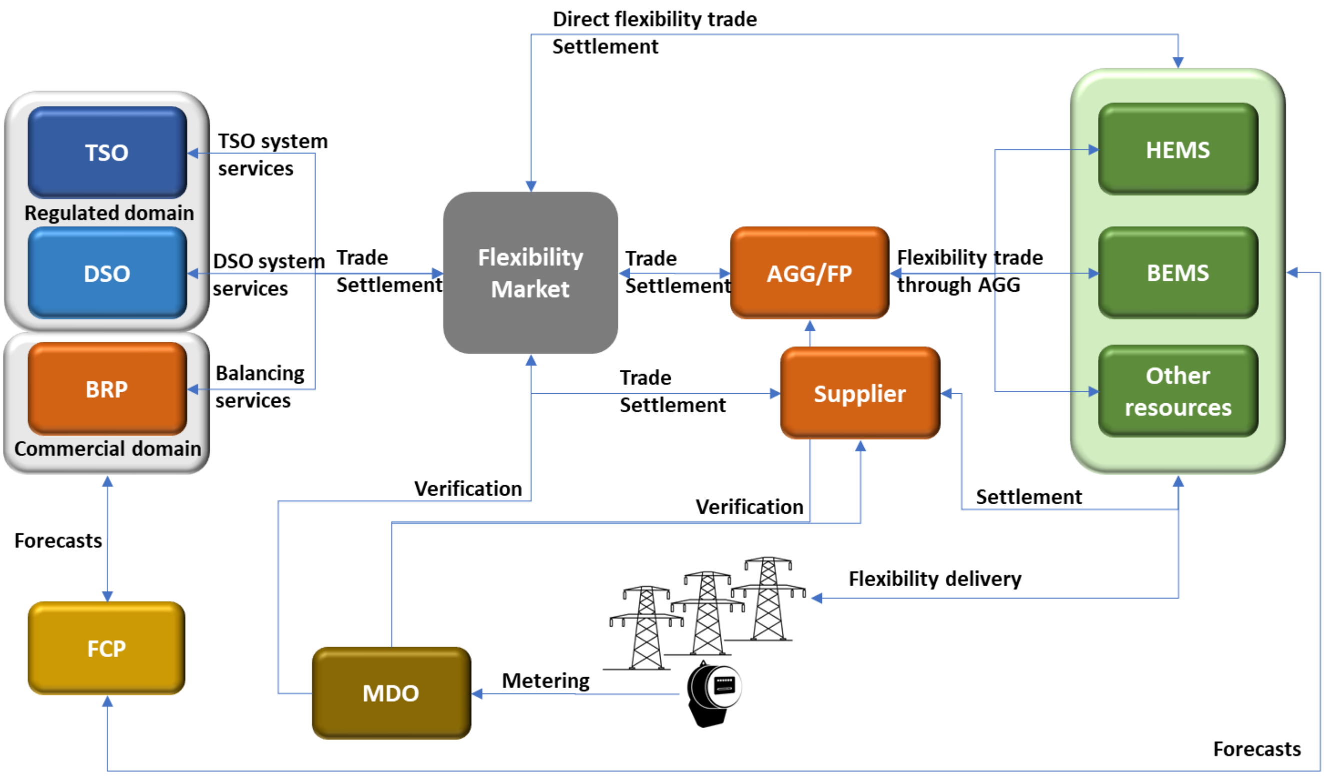

FIGURE 1 – INTERACTIONS BETWEEN ACTORS FOR FLEXIBILITY PROVISION.

2.2 CHARACTERIZATION OF FLEXIBILITY SERVICES

From the point of view of system operation, flexibility can be defined as "*modification of generation injection and/or consumption patterns, on an individual or aggregated level, in reaction to an external signal (price signal/network tariff/activation) to provide a service within the energy system. The parameters used to characterise flexibility include: the amount of power modulation, the duration, the rate of change, the response time, the location etc*." [12][13]. Flexibility services include market-based mechanisms to help solve one or more needs of specific actors, according to specific requirements. This section reviews the needs and services that can be provided to the DSO, TSO and BRP, considering the results from several European projects.

Understanding the main DSO grid services is of especial relevance for Interconnect project to guide this functional specification of the DSO standard interface for market platforms interaction. In addition, since DSOs have also the role of facilitating the use of distributed flexibility to other parties, such as TSOs and BRPs, understanding how this flexibility can be used is also relevant for the DSO interface specification, as will be shown later. Therefore, this section reviews the needs and services that can be provided to the DSO, TSO and BRP, based on previous analysis and results from several European projects. For the TSO case, only a summary is included, since a more extensive revision of TSO system needs, and services is provided in Annex 1.

European DSOs operate different voltage level grids, ranging from LV to MV or even HV. Voltage levels at which the flexibility resources are located affects the flexibility mechanisms in many and fundamental ways, namely:

- The higher the voltage, the closer to simple power-duration "rectangle" products the flexibility services may be. At lower voltages, DSO require more structured products since simple power-duration "rectangle" products may not be economically relevant.
- At lower voltages, liquidity and depth of flexibility markets is a significant issue, and the availability of a flexibility service is usually not guaranteed for every time horizon or time-frames (from years/months ahead to real-time intraday).

2.2.1 CHARACTERIZATION OF DSO FLEXIBILITY SERVICES

Table 1 presents the services which will tackle distribution network technical needs according to the results from [3], [14].

TABLE 2 – DSO NEEDS AND SERVICES DEFINITIONS.

Needs	Services	Definitions
Control of physical congestion	**Congestion Management:** -Corrective (Near real-time) -Predictive (intraday or day(s) ahead) -Planning (months ahead)	Services to mitigate congestions (a condition in which insufficient energy is provided to consumers due to physical limitations of the network) that can be caused by high power consumption during peak hours, concentrated charging of EVs or excessive power generation from DGs, among others.
Control of voltage violations	**Voltage Control:** -Corrective (real-time) -Predictive (intraday or day(s) ahead) -Planning (months ahead)	Services that aim at maintaining voltages within specific dead bands and restore their values to the normal range after grid disturbances occur, to minimise reactive power flows, investments, and technical losses. Voltage control may also be achieved through proper settings of equipment (reactive / active power settings).
Deferring network investments (1 to 3 years' timeframe)	-Voltage Control (Power based) -Congestion Management (Capacity Based)	Services that aim at using flexibility in the context of network planning to solve either current or forecasted physical congestions related to reduced network capacity (overload or voltage violation).
Power quality and loss reduction	Phase balancing	Service to maintain the balance of loads among phases to reduce losses, increase the distribution network capacity, reduce the risk of failures, and improve voltage profiles.
Support for extreme events	-Islanding -Blackstart -Emergency load control/interruptible load/DER -Backup generation capacity	Services designed to increase the resiliency of distribution networks for a quick recovery from extreme events (driven mainly by natural disasters and extreme weather, whose frequency and severity might increase as a direct impact of climate change).

The InterConnect smart energy reference architecture is expected to increase the flexibility of LV and MV loads, enabling optimal energy management for individual, community and grid support purposes.

Since the focus of the Interconnect project is on the congestion management and voltage control services, the remainder of this chapter provides some additional relevant details on these specific services. Indeed, those HLUC oriented to DSO grid flexibility services deal all of them with flexibilities for grid constraints (that is, voltage control and congestions management) as can be seen in Table 1.

Congestion Management

Grid congestions are caused by exceeding the power capacity of an asset (current-related) or because the defined voltage interval for an entire network area is not maintained (voltage-related). However, congestion management generally refers to current related congestions since voltages issues are addressed independently due to their requirements.

Congestions can result in insufficient energy provided to the consumers due to the physical limitations of the network, and can be caused by equipment failures, high power consumption during peak hours, concentrated charging of EVs or excessive power generation from DGs, among others.

Services to solve congestions depend on the triggering event. Faults such as short circuits normally require fast and automated services to correct the problem in real time (corrective service based on automatic active power flexibility activation, grid reconfiguration, etc), intraday and day-ahead services are to solve forecasted congestions (predictive service based on active power flexibility reservation and/or activation, grid reconfiguration, etc.), and network planning analyses future scenarios and plans measures to reduce and avoid bottlenecks in the long term (long term service based on active power flexibility capacity reservation, grid reinforcement, etc.).

Table 3 summarizes the services related with congestion managements, considering the triggering event, time frame and a brief characterization of the service.

TABLE 3 –SERVICES FOR CONGESTION MANAGEMENT.

Service	Detection event / Trigger	Time Frame	Characterization
Corrective	Failure	Near real-time	Automatic or manual active power activation, network reconfiguration
Predictive	Failure Forecast infeed / load	Intraday, day(s) ahead	Active power reservation and/or activation, network reconfiguration
Planning	Construction planning / maintenance	Months/years ahead	Active power reservation, grid reinforcement

Table 4 focuses on some relevant parameters of the congestion management service from the perspective of a short-term flexibility market (day-ahead or intraday markets for predictive network management), as it is the focus of Interconnect project. While in some cases these parameters may be part of the technical specification of the service, and therefore be implicit and mandatory in the product specification (and prequalification processes), others may be part of the information of the product being offered. This may also depend on the complexity of the bid’s selection algorithm.

TABLE 4 – SERVICE AND PRODUCT PARAMETERS FOR CONGESTION MANAGEMENT.

Parameter	Predictive Congestion Management
Product offered	Average active power for the delivery time (energy)
Price	Per energy block offered for each delivery time.
Reservation and/or activation	Reservation and activation possible

Mode of activation	Manual
Expected duration of the response	As soon as the forecasts permit an evaluation of the measures but no later than gate closure time or regulatory imposed limits.
Activation time	Activation time should be aligned with thermal limits. However, products could specify available ramp. Bid selection should consider this parameter if needed.
Locational need/ Geographic scope	Product must specify location or must be stored at the resource registering process.
Aggregation	Limited by nodes or zones.
Deactivation period	Products could specify a deactivation ramp. Bid selection should consider this parameter if needed.
Minimum duration of delivery period	15 min seem to be a typical value. Although the duration of the flexibility activation can be the result of the selection of different bids, for simplicity a minimum duration should be foreseen.

Voltage control

Voltage limits are limited by various national and international regulations. For example, standard EN50160 establishes acceptable deviation from the nominal value should be within + - 10% and limited in time. Voltage deviations can affect the correct operation of different types of loads and DER, namely electronic loads, induction machines and inverter-based DER. In extreme cases, severe voltage disturbances can also lead to voltage collapse, compromising the system stability.

Voltage control services aim at keeping voltages within their safe bands and to restore their values to the normal range after grid disturbances occur, to minimize reactive power flows and technical losses. As voltage problems are mainly local, they must be addressed with local tools or services. DSO traditional tools include transformer tap changers and compensatory assets (FACTS, shunt reactors, capacitor banks) locally or centrally controlled, as well as network reconfiguration. New services for voltage control can be based on power factor control, reactive power flexibility, or active power flexibility such as DER curtailment or demand response.

Table 5 summarizes the services related with voltage control, considering the triggering event, time frame and a brief characterization of the service.

TABLE 5 – SERVICES FOR VOLTAGE CONTROL.

Service	Detection event / Trigger	Time Frame	Characterization
Corrective	Failure	Near real-time	Automatic active and reactive power activation, OLTC and compensatory assets (FACTS, shunt reactors, capacitor banks), network reconfiguration
Predictive	Failure Forecast infeed / load	Intraday, day(s) ahead	Active and reactive power reservation and/or activation, OLTC and compensatory assets (FACTS, shunt reactors, capacitor banks), network reconfiguration
Planning	Construction planning / maintenance	Months/years ahead	Active and reactive power reservation, network reinforcement

Table 6 focuses on some relevant parameters of the voltage control service from the perspective of a short-term flexibility market, as it is the focus of Interconnect project. While in some cases these parameters may be part of the technical specification of the service, and therefore be implicit and mandatory in the product specification (and prequalification processes), others may be part of the information of the product being offered. This may also depend on the complexity of the bids' selection algorithm.

TABLE 6 – SERVICE AND PRODUCT PARAMETERS FOR VOLTAGE CONTROL.

Parameter	Predictive Voltage Control
Product offered	Average active or reactive power for the delivery time (energy)
Price	Per energy block offered for each delivery time.
Reservation and/or activation	Reservation and activation possible
Mode of activation	Manual
Expected duration of the response	MV: from seconds up to 1h LV: up to 6h (e.g., at the peak of photovoltaic generation) Products could specify the available duration.
Activation time	Activation time should be aligned with thermal limits. However, products could specify available ramp. Bid selection should consider this parameter if needed.
Locational need/ Geographic scope	Product must specify location or must be stored at the resource registering process.

2.2.2 CHARACTERIZATION OF TSO FLEXIBILITY SERVICES

Distributed flexibility is local in nature, and, as such, can offer local or global flexibility services to TSOs, in coordination with those DSOs affected so that the flexibility activation by TSOs does not cause grid problems at the distribution level. Those potential services are mainly for balancing, congestions management and voltage control, and could be based on active (balancing and congestion management services) or reactive power (congestions management and voltage control).

Although less frequently addressed, it is also expected that distributed flexibility could provide support to TSO black-start or islanding operation services, since a large amount of the generation capacity will be at the distribution level. Similarly, inertia system needs may also be provided in the future by assets located at the distribution level.

Table 7 summarize these TSO services, and Annex 1 provides a more extensive and detailed revision of TSO system services. From Deliverable D1.2, those HLUC more related with TSO services are the Italian pilot HLUC 1 and the French Pilot HLUC 02, although the later relays on the implicit flexibility mechanisms of dynamic tariffs.

TABLE 7 – TSO NEEDS AND SERVICES THAT COULD BE PROVIDED BY DISTRIBUTED FLEXIBILTY.

Needs	Services	Comments
System balancing	TSO automatic and manual reserves with different operation time frames. These are non-local services.	Depending on the voltage level where the flexibility is located, and thus, on its size, aggregation must be needed to provide significant balancing power to the TSO. FSP should comply with all service's technical requirements, which should also be adapted to allow and promote distributed flexibility participation.
Inertia	Although inertia also refers to balancing issues, it has special physical characteristics that make it different from reserves. This is a non-local service.	Inertia can be a structural physical characteristic of the grid connected assets or be simulated with very fast energy injection. Distributed resources could provide both.
Grid constraints	Congestion Management and Voltage Control local services, both for different time frames: -Corrective (Near real-time) -Predictive (intraday or day(s) ahead) -Planning (months ahead)	Services to mitigate lines overloading and keep voltages inside their nominal ranges. Distributed flexibility can contribute at the TSO-DSO connection points with active and reactive power.
Emergency or extreme events services	Under emergency situations, blackstart or islanding services may be needed for service restoration and for limiting the grid zones with no supply.	Distributed generators can provide generation backup capacity for system recovery. In addition, islanding may also contribute to both, limiting grid zones without supply and helping to system recovery. Note that (see DSO grid services) islanded operation needs to replicate balancing system services at local level.

2.2.3 CHARACTERIZATION OF BRP FLEXIBILITY SERVICES

Until close to real time, balance responsible parties have the possibility of managing their imbalances in commercial flexibility markets such as intraday markets. After this last trading opportunity their energy commitment cannot be modified. Comparing it with the metering data for each settlement time unit allows to compute their imbalance for which they are responsible. Imbalance settlement rules vary among different regulatory frameworks.

System imbalances are managed by the corresponding TSO which makes use of the different available reserves to compensate the imbalances. Balancing costs are then supported by final consumers and by those BRP that contribute to the imbalance. Note that different imbalance settlement rules can be applied. Note also that BRP objective is not necessarily to reduce imbalances, but to optimize their portfolio considering all available energy trading opportunities. As an example, individual imbalances with a sign contrary to the system imbalance are very often not penalized or subject to balancing charges.

In theory, the BRP may procure power from day-ahead, intraday and even local markets. It should be noted that the BRP is more of a role than an actor. A retailer or an Aggregator may play the role of a BRP, or the role delegated to a third party.

TABLE 8 - SUMMARY OF BRP NEEDS.

Needs	Triggering	Time Frame	Flexibility Service
Portfolio Optimization	Generation/consumption deviation from planned/ contracted operation	Operation Timeframe, Short-Term (day-ahead. Intraday)	Energy balancing in commercial energy markets (such as intraday markets)

TABLE 9 - PRODUCT PARAMETERS FOR BRP FLEXIBILITY SERVICE.

Parameter	Portfolio optimization
Product offered	Average active power for the delivery time
Price	Per block offered for each delivery time
Ramps	Depending on the market, clearing can take or not ramps into account

2.3 IMPLICIT AND MARKET-BASED FLEXIBILITY MECHANISMS

Implicit flexibility is the flexibility provided by reacting to price signals (energy and grid access tariffs). By providing the appropriate price signals, a more efficient use of the grid can be obtained by the adaptation of the behaviour of the grid connected resources. The main income stream comes from the saving this behaviour adaptation can achieve.

On the contrary, explicitly flexibility is the flexibility provided by an explicit activation, must be therefore dispatchable, and is usually managed and facilitated by aggregators that trade it on different markets (wholesale market, commercial and regulated balancing markets, or other system services markets). Flexibility provision benefits come from the remuneration for the services provided to the BRP at the commercial level, or to the TSO and DSO at the regulated level, [18][19]. Explicit flexibility can also result from smart connection agreements, also named conditional connection agreements. Such agreements do not usually yield to remuneration of the flexibility service but to cheaper connection costs.

As described in [20], the DSO solution space consist of four main areas: DSO Tariff Solutions, Connection Agreement Solutions, Rules-Based Solutions and Market-Based Solutions. These possible alternatives are summarized below and those more relevant for Interconnect are discussed in more detailed in the following sections.

DSO Tariff Solutions

Through an appropriate network tariff structure, network users can be incentivized to use the networks more efficiently by adapting their behaviours to the tariffs signal prices. In this sense, they could, for example, charge their EVs slowly after midnight instead of selecting fast charging during network peak hours.

Therefore, network tariff structures that really reflect the cost incurred by the behaviour of the connected customer are necessary to unlock their implicit flexibility, being complementary to other explicit flexibility acquisition mechanisms.

A tariff structure is composed of multiple elements that can also be combined, namely:

- Tariff basis: can be based on power capacity but also on energy consumption.
- Timing: can be fixed (evening peak hours, 17:00-19:00) or dynamic (e.g., depending on the current state of the network, area or market).
- Direction: consumption or production.
- Location: tariff structure per DSO area or a locational tariff.

However, tariff structures do not always solve the DSO problems, and a trade-off between efficient economic signals and complexity is needed. Indeed, too simple tariff structures, e.g., always higher between 17:00-19:00, can lead to high peaks just after 19:00, but very complex schemes may not be understood and therefore may not be used by consumers. Therefore, not too complex cost reflective tariff seems a very good starting point anyway.

Connection Agreement Solutions

Contractual agreements can introduce a variable network access or flexible connection agreement for certain generators or consumers. Based on financial incentives (e.g., cheaper connection costs), the customer accepts to be curtailed usually with no compensation. Choice is given to the customer, who balances the effect of both scenario on its business operations and business plan. The cheaper connection cost stems from the agreed curtailment that enables the DSO to not reinforce the network avoiding the corresponding reinforcement costs.

Rules-Based Solutions

Another technique for enabling DSOs to access flexibility may be through rules-based solutions. Rules-based solutions refer to compulsory rules in network codes and regulation to impose flexibility technical requirements. An example could be that PV infeed is curtailed if certain technical limits are reached.

A rules-based solution can also be the result of a market failure and therefore should be seen as an exception. Such approach can be justified when there are not enough voluntary offers to prevent a blackout. In general, a rules-based solution should not be used where a market approach is viable.

Potential compensation mechanisms for loss of revenue and loss of opportunity costs of providing flexibility from generators whose production is curtailed, should be determined by the regulator. Rules based solutions can help when other solutions fail, for example when the market do not function due to gaming or lack of liquidity or when rule based-solution is the most cost-efficient solution, that is when "the procurement of market-based services is not economically efficient or that such procurement would lead to severe market distortions or to higher congestion", as in Directive (EU) 2019/944 [21].

A rules-based approach fits the red phase of the traffic light concept [22]. The traffic light concept is such that, in the green phase, no flexibility services are required by the DSO, in the orange phase, flexibility services from customers and market parties are required using market mechanisms, while in the red phase, there is a direct risk to the system and the DSO overrules the market to intervene directly using non-market regulated measures. However, if there are not enough or acceptable flexibility services offered, a rules-based approach is needed to prevent a black-out (red phase).

Market-Based Solutions

Market-based solutions can deliver cost-efficient and innovative solutions driven by competition for the provision of services when they are locally available (in number and volume). There are several options to implement such a market mechanism, e.g., via a competitive tender or a market platform. For such a market, different FSP compete to provide flexibility services to the DSO.

The firmness (in terms of reliability) of market-based solutions is very important, especially for congestion with local consequences. Flexibility is a transfer of risk to flexibility providers, which must effectively manage that risk. One must keep in mind that a flexibility service failure will lead to an outage for part of the network, that another solution could have prevented. Reliability is therefore essential to build the necessary confidence between parties to foster the development of flexibility markets, and switch from experiments to industrial business models.

Once a service provider has sold a service, the system operator must be able to rely on the delivery of that service. If the service is not delivered, penalties can be defined based on the balance between the service criticality (such as the value of lost load in case of a failure) and the service provider risk of not delivering the contracted flexibility. The penalty must incentivize the flexibility provider to be reliable and cannot be so low that the service provider will simply pay the penalty to earn more money with the specific unit in another market. The flexibility service provider must manage the reliability issue (technically and/or financially) that is the potential failure of flexibility sources within its portfolio. If it cannot achieve the required reliability, it should not enter the market on its own. A low reliability service could however be integrated in a broader aggregated portfolio, among which reliability can be managed. Typically, this means contributing to solve issues at higher level of tensions or balancing.

It is also worth mentioning that, once flexibility is used by the DSOs, the market knows where grid constraints are present at that moment. Therefore, regulations and market design need to avoid market distortion.

Next section summarizes in more detail tariffs solutions and market-based mechanisms for their relevance in Interconnect demonstrators.

2.3.1 DYNAMIC NETWORK AND ENERGY TARIFFS

Dynamic tariff is an implicit flexibility mechanism, where the consumers have the possibility to shift their load according to price signals that reflect the system and market conditions. The most common types of dynamic tariffs are time-of-use (ToU), real-time pricing (RTP) and critical peak pricing (CPP) [24].

Dynamic tariffs can be defined to reflect network operating conditions. This can help DSO manage the network with high shares of RES or EVs, incentivizing consumers to shift their flexible loads to periods with higher generation or lower loads, avoiding potential congestion and voltage problems. However, network operating conditions are usually reflected in a single component of the network access costs composing the tariff, meaning that it will result in a very reduced economic benefit particularly in the LV consumers.

On the other hand, an energy dynamic tariff can be defined by the service provider to reflect market electricity prices and to help manage their load and DER portfolio. In fact, the increased uncertainty associated to loads and DER could potentially lead to forecast errors, resulting in the need to either buy more power at the market (which would result in higher costs) or to shift the customers' demand. As many devices are not capable (or willing) to be shifted directly, a mechanism to trigger the devices to shift their demand themselves is needed [24].

Conceptual description

In InterConnect the implementation of dynamic tariff is being considered. As shown in Figure 2, the DSO and the Energy Service Provider (ESP) or supplier send the price signals through incentive tables to the home or building energy management system (EMS). The EMS will then manage the connected smart devices to optimize the power consumption according to the communicated incentives (e.g., price, CO2 emission, etc.) according to consumer preferences and appliances limitation.

Figure 2 shows an example of a full dynamic tariff sent by the ESP to its customers, based on the network dynamic tariff defined by the DSO. This means that, in this case, the DSO only interacts with the ESP, responsible for sending the updated incentive table to the consumer EMS. However, alternative scenarios from Figure 2 could take place, depending on the regulatory context and on the contractual relation among consumer, supplier and DSO.

Each incentive table with a tariff can have multiple tariff levels (called "tiers") which have one or more incentives (e.g., absolute price, CO2 emission, etc.). Based on the incentives, the EMS can calculate where to plan the consumption and production cycles of its managed appliances.

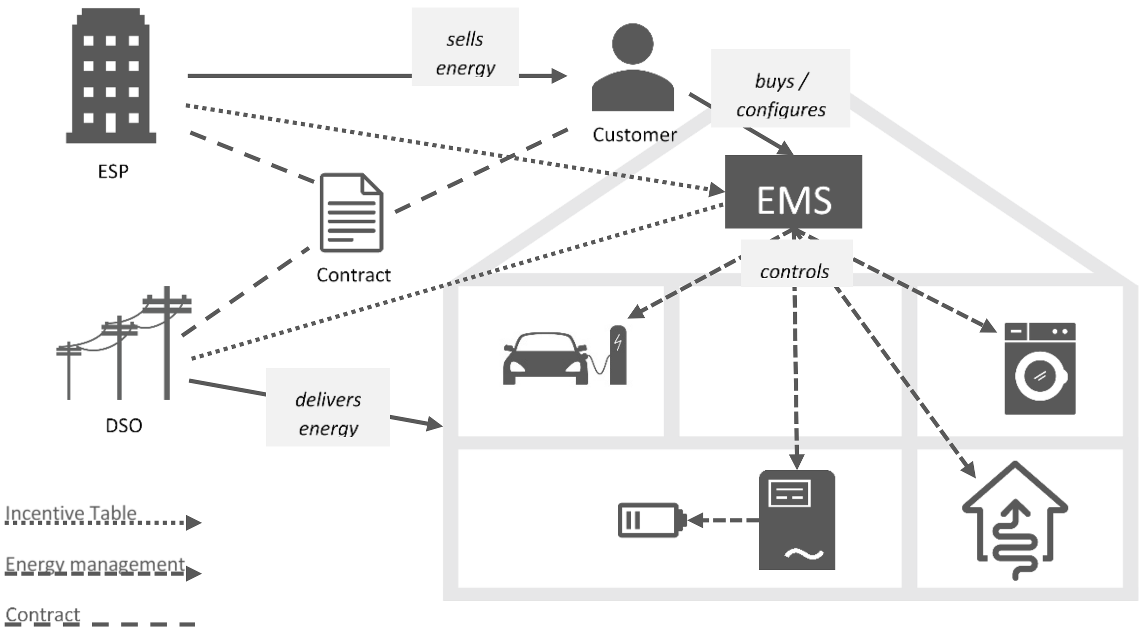

FIGURE 2- OVERALL SYSTEM SETUP EXAMPLE

Processes

As referred previously, the dynamic tariff is composed by two main costs:

- Network access costs, (in Figure 2 included in the incentive table) provided by the DSO to reflect network operation conditions. The network access costs will be typically regulation dependent, defining standard calculation methodology.
- Price of energy (PoE) defined by the ESP pricing strategy that should consider electricity and flexibility market conditions. The price of energy represents the costs (when consuming) or profits (when injecting to the grid) charged or paid by the ESP, and depend (among others) on the price the ESP sees at the electricity stock market, the consumption/production of the other households the ESP has contracts with, etc.

The total costs (or profits) for the energy consumed (or produced) by the household are therefore composed of several individual positions, depending on the country's regulations, the contract, etc. The two main positions are the price of energy (PoE) that is billed by the ESP and the network access costs that is billed by the DSO. Depending on the overall system setup, either the ESP combines both positions within its incentive table ("total price", PoE+network access costs), or they are transmitted separately by ESP and DSO to the EMS.

Data exchange

Tiers are used to model different levels within the tariff. There are several possible triggers to switch to another tier:

- Time trigger, changing the prices at certain points in time
- Power trigger, changing prices for specified power limits
- Energy trigger, changing prices for specified energy consumption in a given period (e.g., the first day of the month)

Incentives quantify the costs of energy but can also include estimated CO2 emissions or RES share in energy consumption. The incentives are always bound to a specific tier. When the tier switches, the corresponding incentives become valid.

The time-based incentive information provides slots within the incentive table, each with values for the incentive(s) (there can be more than one for each time-period, e.g., absolute price and CO2 emissions).

As referred previously, two distinct incentive tables are considered: one for the Price of energy (PoE) and the other for the network costs.

Figure 2 already showed how an overall system setup could look like. A customer has a contract with the ESP that sells the energy the customer's appliances consume. The DSO ensures electricity supply to the customer's house. The EMS receives incentive tables from the ESP as well as from the DSO to control the connected appliances in an optimized way.

Figure 3 presents the sequence diagram with the identification of the data exchange between the different actors and systems.

2.3.2 FLEXIBILITY MARKET FRAMEWORK

According to existing flexibility markets frameworks such as those proposed by USEF or ENEDIS (described in Annex 3) and to other existing initiatives (such as in [25]-[27]), this section proposes a general, but simplified, framework for local flexibility markets adapted to the Interconnect project needs. Market mechanisms, at this description level, depend on the TSO-DSO coordination mechanism selected, and as such, it was decided to opt for one of the most common approaches (well suited to Interconnect needs) corresponding to a local DSO flexibility market with some potential coordination with the TSO, as described below. Annex 4 provides a brief revision of the main TSO-DSO coordination mechanisms.

The main phases to enable this local flexibility market are depicted in Figure 4, where the focus is on DSO flexibility usage for short-term grid operation.

1. **Registration** should take place once, when a FSP requests to participate in the market. Information related with the assets (location, maximum flexibility range, aggregator or FSP managing it, etc.) should be provided so the DSO can use it for its grid analysis and the potential impact of this flexibility.
2. **Pre-qualification** can adopt different levels of complexity and efficiency, and may imply the participation of both, TSO and DSO depending on the flexibility buyer. TSO could also pass the pre-qualification responsibility to the DSO by means of an agreement. Pre-qualification may imply:
    - Product-prequalification, to verify that the resources are able to technically provide the flexibility according to the technical requirements of the services or the product defined for the service.
    - Grid-prequalification, to verify that the resources can provide the flexibility considering the technical constraints and characteristics of the grid where they are connected to.

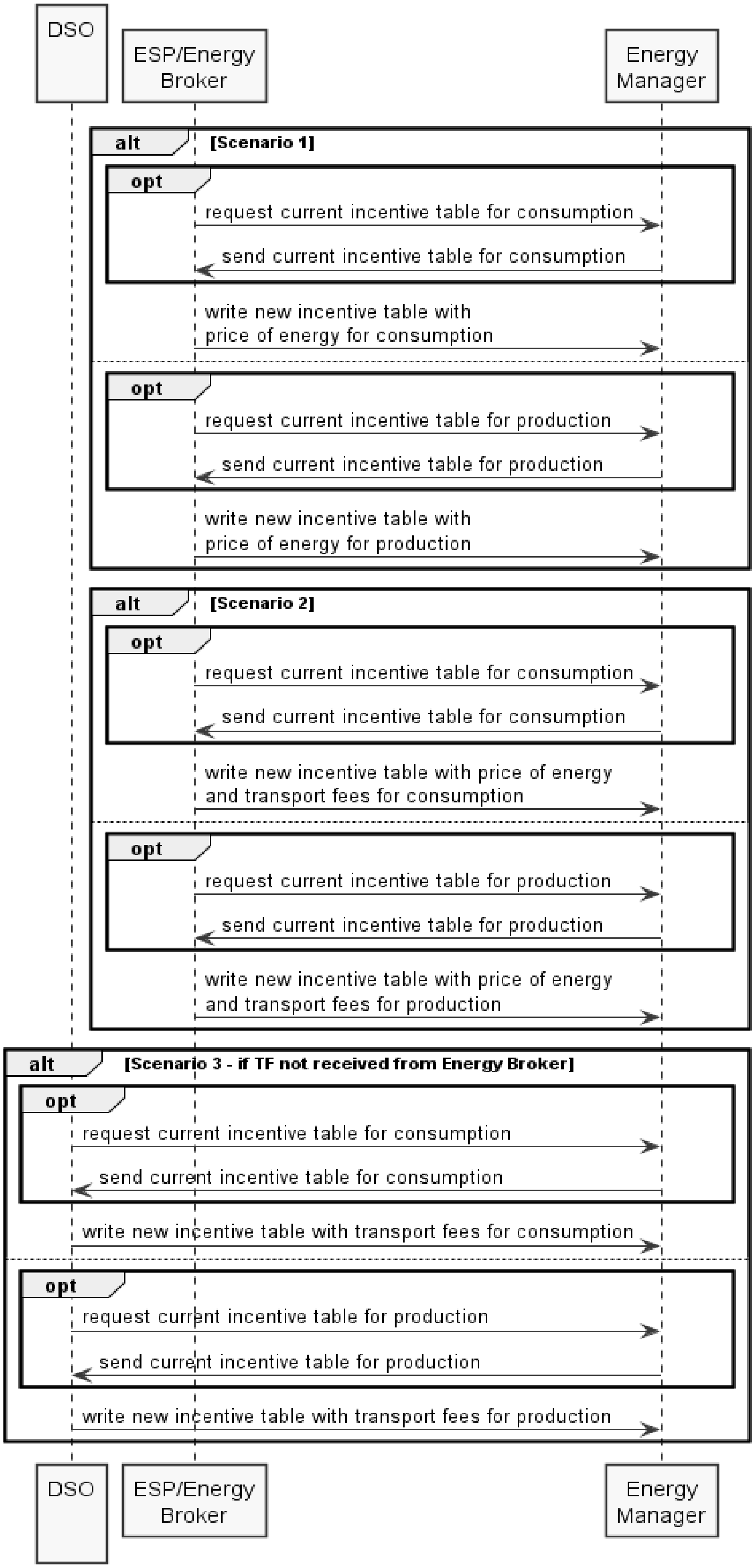

FIGURE 3 - SEQUENCE DIAGRAM FOR INFORMATION FLOW.

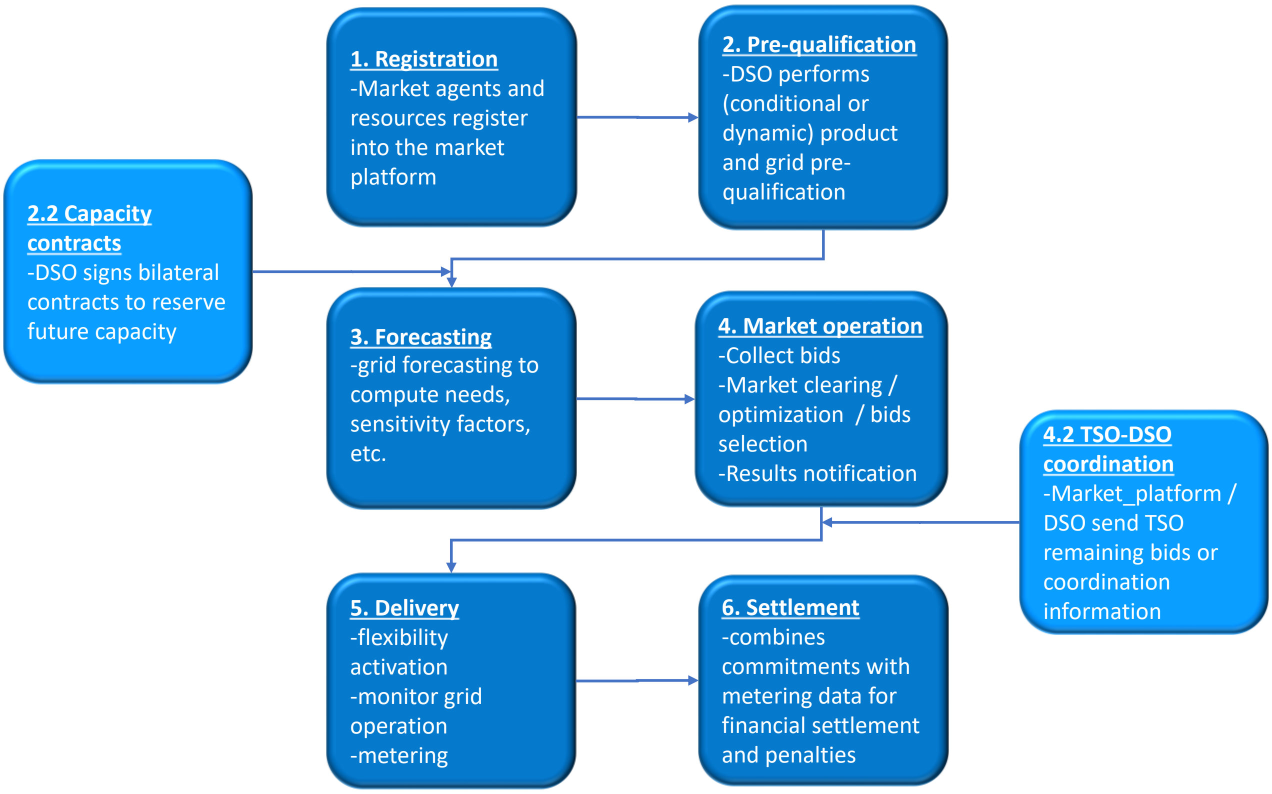

FIGURE 4- MARKET PHASES AND FUNCTIONS TO ENABLE LOCAL FLEXIBILITY MARKETS

In addition, pre-qualification can be conditional, to limit the flexibility range under certain grid conditions previously defined, or dynamic, more complex but more efficient since limitation becomes dependent on the real grid condition and the flexibility range is maximized accordingly.

3. The **forecasting phase** corresponds to the use of forecasts to assess the flexibility needs. Depending on the DSO criteria, this may result also in the publication of the needs to incentivize the participation of the FSP in the market, and in the so-called congestions zones to define topological grid regions where resources can be aggregated due to their similar impact on the grid. This also can help FSP to manage efficiently their portfolio of resources deciding the aggregations dynamically according to the DSO grid needs, and the DSO to reduce bids fragmentation.
4. The **Market operation** corresponds to the processes of receiving the bids, the bids selection or market clearing. The resulting price or prices will depend on the selected method: either pool-based where uniform pricing or pay-as-cleared are preferred, or continuous bilateral market where each transaction is closed at the price of the FSP bid. The selection or market clearing could be performed inside the market platform (independently if it is operated by an independent MO or by the own DSO with the corresponding regulatory supervision), in which case, grid information is needed to consider the grid constraints and the problem to be solved. However, it can also be performed in an external process, in which case, the market platform limits mainly to register the bids and the selection results of each market session.
5. The **Delivery** phase implies the activation of the selected flexibilities to deliver the product committed, which also involves monitoring the grid operation to verify that the activated

flexibilities have the expected result and metering the resources providing flexibility to verify that the committed products are properly delivered.

6. Finally, based on the market results and on the verification process the **settlement** determines the final economic transactions to the FSP. In case the TSO and the DSO needs are solved jointly (for example if the coordination is done by including, in the bids selection process, a constraint to comply with a particular power profile at the DSO-TSO interface), then, criteria must be established to share the flexibility cost between TSO and DSO.

Additional processes can be capacity contracts before day-ahead and intraday market sessions, and possible coordination with the TSO to provide it the available distributed resources or relevant coordination information, although the focus of Interconnect is on the DSO flexibility usage. Several coordination mechanisms can be found in the literature. However, since the focus of Interconnect is on the DSO, the simplified approach of Figure 5 is proposed as a reference for the local flexibility market (see Annex 4 for a revision of the main TSO-DSO coordination mechanisms). As can be seen, a local flexibility market is used by the DSO to select the flexibility needed for solving its grid problems. However, as already said, several degrees of coordination with the TSO could be considered, such as:

- Agree an active power profile at the TSO-DSO interface.
- Send local bids not used by the DSO to the TSO for its own use.
- Send balancing information for the TSO to compensate local generated imbalances (which would have sense only in case of a significant impact).

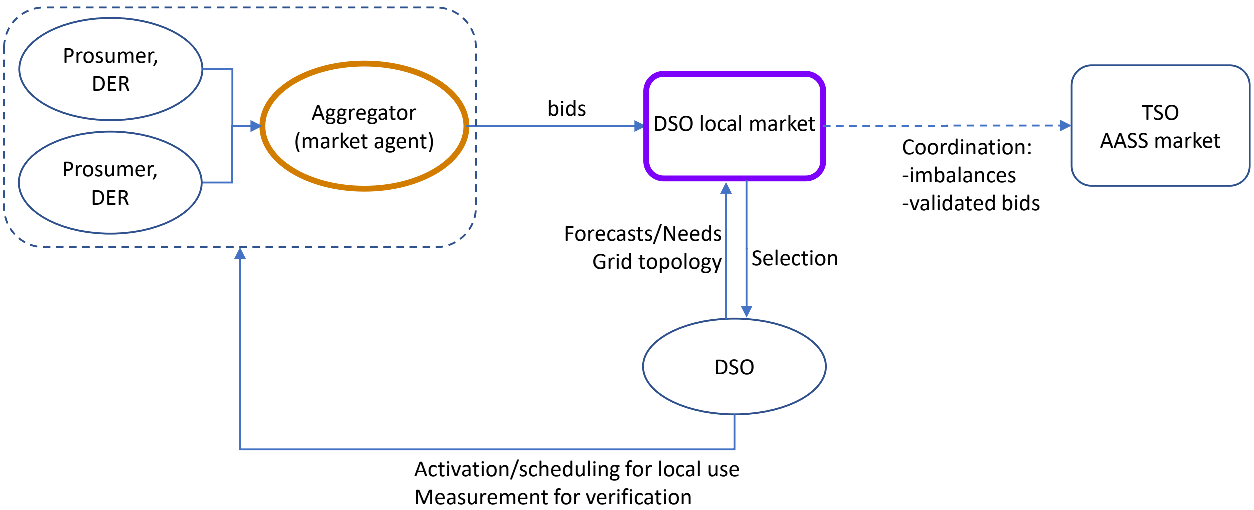

FIGURE 5 - DSO LOCAL FLEXIBILITY MARKET WITH POSSIBLE TSO COORDINATION

According to the phases and local market choices indicated up to now, Figure 6 shows the main workflow to highlight the different data exchanges according to the process needed at each of the market phases of Figure 4. Note that, for simplicity, registering and pre-qualification have not been represented since they are not (usually) continuous processes as are the other ones. Note also that some of the functions assigned to the market platform could be performed at the DSO side.

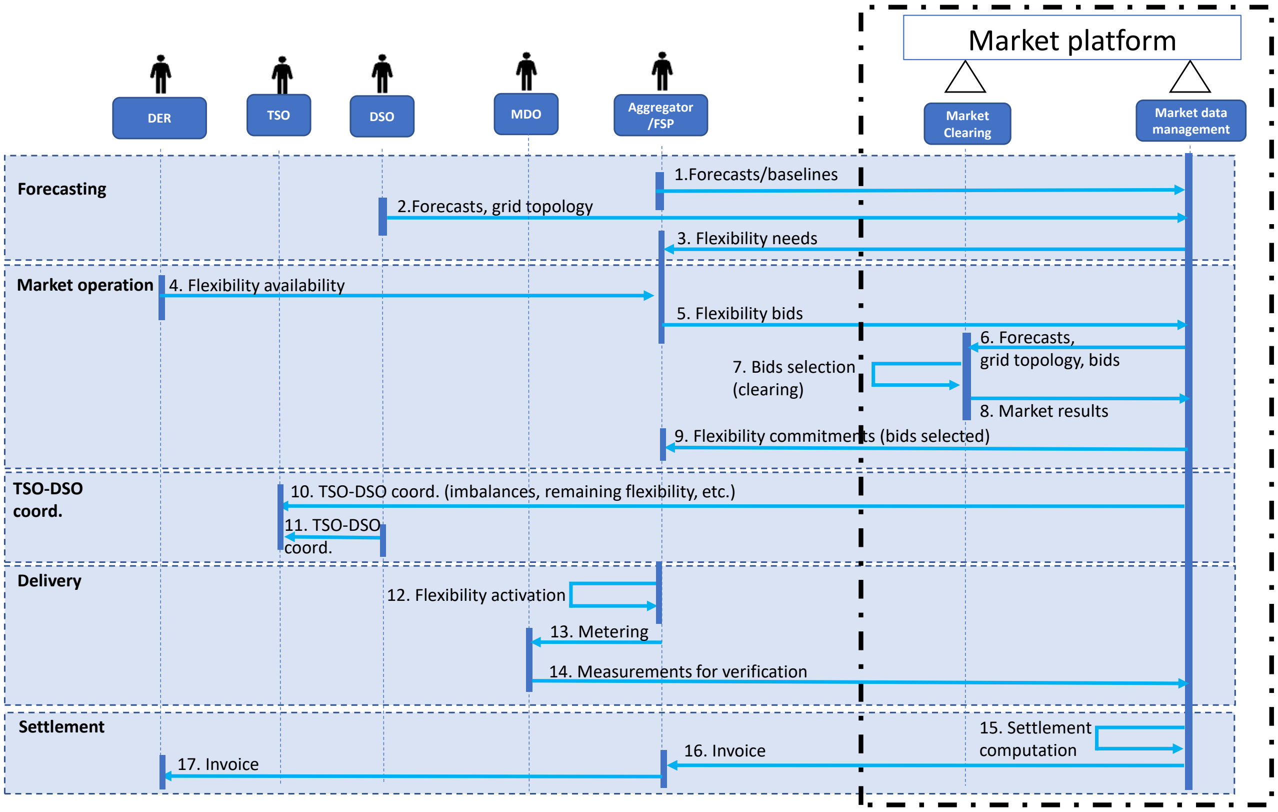

FIGURE 6 - INTERCONNECT LOCAL FLEXIBILTY MARKET WORKFLOW

At steps 1 and 2 resources baselines and forecasts are used, in conjunction with the grid information, to assess the flexibility needs, which can be published (step 3) to help the FSP to optimize their portfolios with the appropriate aggregations.

Step 3 can also define congestion zones, where DSO considers that the resources can be aggregated due to a similar impact on the grid.

At step 4 the resources/assets owners send their availability to provide flexibility to the FSP that represents them in the market. With all this information the FSP prepares and sends the bids to the market platform (step 5). Bids can include the resources and, depending on the clearing process, some additional information such as ramps, maximum energy and other complex transversal conditions can also be part of the bid, especially for market with larger delivery horizons.

Steps 6, 7 and 8 correspond to the market clearing process (bids selection), and the output is made available to the FSP at step 9. This selection process should be the result of a cost minimization considering the different resources available to solve the identified needs, for example using an optimal power flow or some alternative algorithm based on sensitivity coefficient.

After the clearing process, depending on the existing coordination between TSO and DSO, steps 10 and 11 can represent this data exchange in a very simplified way. If the coordination allows the TSO to used remaining local market bids, the DSO may want to validate those selected by the TSO before their activation. However, for simplicity this process has not been described or represented in detail.

Step 12 is the FSP activation of the flexible resources selected. The detail of how this activation is performed has not been represented, and different options could exist. Step 13 represents the metering process the MDO performs of the asset’s performance, which sends the data (step 14) to the market platform for verification.

Step 15 is the settlement computation which combines the committed flexibilities at the corresponding price (depending on the market mechanism selected) and the verification process which may imply extra costs and/or penalties in case the flexibility was not properly delivered, according to the commitment resulting from the market. The settlement (step 16) is invoice to the FSP, which in turns has to settle with the resources of its portfolio participating in this market session (step 17).

2.3.3 TSO-DSO COMMUNITATION INTERFACES

TSO-DSO coordination mechanism are briefly described in Annex 4. However TSO-DSO communication interfaces are relevant for the DSO interface design and are addressed in this section. Indeed, related to this, [29] provides some general guidelines based on both TSO and DSO own responsibilities, and on some basic principles such as avoiding data duplications, agreeing procedures and data formats for data exchanges, and with the objective of an efficient sharing of the existing flexibility resources. Based on these principles, and on existing proposals of TSO-DSO coordination mechanism, that we believe can be summarized by the aforementioned approaches, they propose the very general conceptual communication interfaces architecture of Figure 7.

This architecture is based on three different interfaces with different purposes:

- **Direct TSO-DSO interface:** this interface is to guarantee the overall system security, stability and resilience. Although different characteristics and implementations are possible, depending on the specific country or system operators' needs and structures, this interface is essential to guarantee:
    - A direct and therefore a secure and fast communication channel for severe grid faults or emergency situations
    - A medium and long-term coordination and control of load flows at the TSO-DSO grid connections.
    - The proper exchange of useful structural and near real-time data, previously agreed by both operators to improve grids observability, resiliency and safety. Among those data are forecasts, real-time needs and resources activation related data.
    - A more efficient grid operation based on a more dynamic agreed operation.
    - An efficient and coordinated use of the available flexibility
- **Shared resources interface:** this interface is used to made the shared resources connected to the distribution grid (loads, generators, storage) available to both operators. Main data shared are structural or almost structural data (such as delivery points identification, resources suppliers) and variable data (such as resources baselines or measurements). Note that some data may be useful for other actors such as aggregators, suppliers or customers, and as such, content and formats should comply with all users' requirements. In this sense, the shared resources interfaces, as shown in Figure 8, could be part of a broader interfaced referred as the Resources Register Interface to provide data services to all additional mentioned parties.
- **Market interfaces:** these interfaces allow customers and aggregators to offer flexibility services to TSO and DSO, where these operators can request and buy these services. Market

interfaces depend on the market organization and coordination mechanisms, considering, in addition, that different grid services could be traded in different (local or system) markets, or be traded in a same (local or system) market. In this sense, additional mechanisms may be needed among those marketplaces to increase coordination to avoid issues like double bidding selection, flexibility activations leading to grid constraints violations (for example with pre-qualification and validations procedures), etc. Therefore, market interfaces can provide basic economic trading functionalities, or include more complex selection procedures to fulfil system operators' needs such as priority rules and coordination procedures to guarantee and efficient flexibility allocation among procurers as well as the non-violation of the grid constraints.

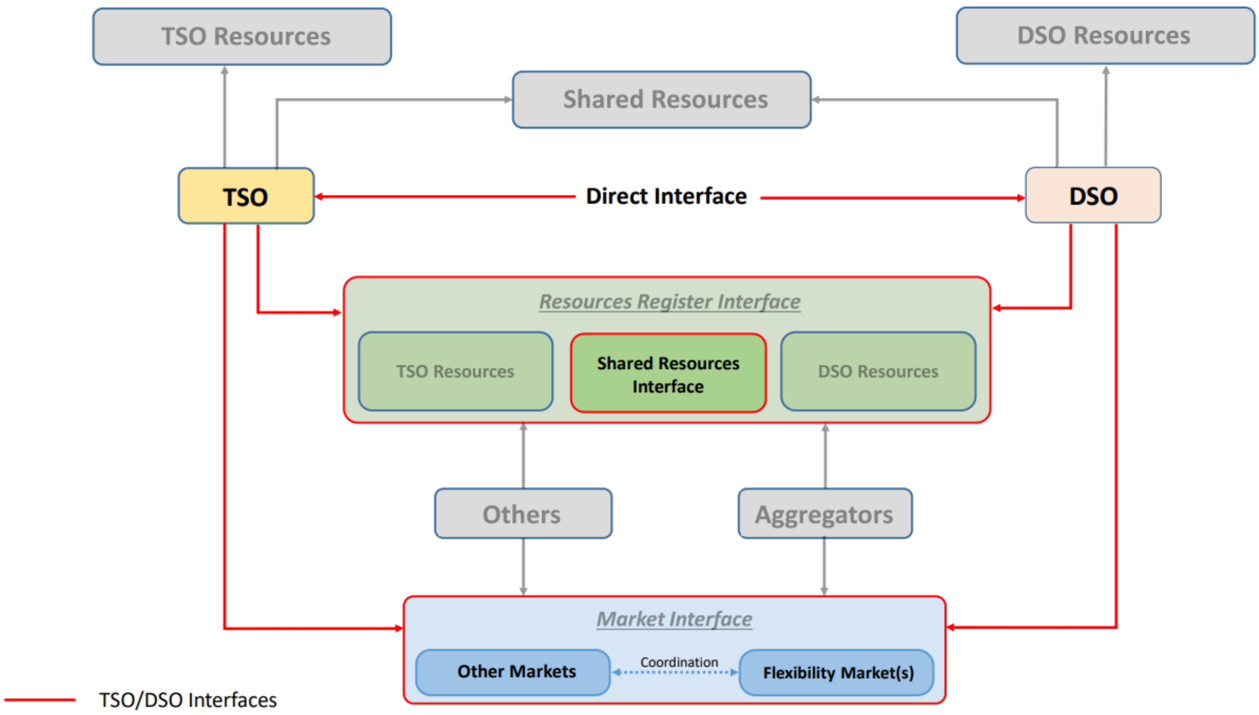

FIGURE 7 - TSO/DSO COORDINATION INTERFACES ARCHITECTURE [29].

3. EU PROJECTS REVIEW OF INTERFACE ARCHITECTURES

Facilitating the use of flexibility from distribution network consumers/prosumers has been the focus of several European projects. In order to implement and test the flexibility mechanisms identified in section 2.3, the projects have developed platforms that allow the generalized provision of flexibility for grid support, while providing other value-added services to consumers and relevant stakeholders.

Considering the main goal of DSO Interface to provide a standard interaction between DSOs and energy and non-energy marketplaces and actors, relevant platforms from other European projects were identified. The analysis of the different design approaches considering their main services, functionalities, architecture and data exchange models will establish the grounds to the specification of the DSO Interface, fostering replicability and interoperability.

This chapter provides a brief overview of four platforms, namely:

- Grid and market hub platform, developed within H2020 InteGrid project to facilitate demand response, smart grid functionalities through regulated energy and non-energy data-driven services.
- E-Flex Platform, developed and demonstrated within H2020 project InterFlex for enabling the local trade of flexibilities for improving distribution network operation.
- Dynamic Coalition Platform, developed in the scope of the H2020 FHP project for the optimal planning and control of clusters of distributed heat-pumps, managing flexibility trading between Grid-Interactive Buildings (prosumers) and local grid operators (DSOs) or flex needing stakeholders (BRPs, TSOs).
- PLATone platform, currently being designed in the ongoing H2020 project Platone, and consists of a layered set of platforms for supporting the DSOs and other involved stakeholders to enhance the observability of the network and the exploitation of the flexibility.

3.1 GRID AND MARKET HUB

3.1.1 GENERAL OBJECTIVES AND DESCRIPTION

The Grid and Market Hub (Gm-Hub) is a neutral data hub, built within the scope of H2020 InteGrid project. This platform enables the link between several classes of stakeholders, establishing an integrated environment to enable demand response, smart grid functionalities, data-driven services and transient data storage. The core of the Gm-Hub platform is built around a set of basic and advanced energy and non-energy services, with which stakeholders engage to, facilitating market access and, most importantly, providing a platform for the creation of new data-driven services.

The Gm-Hub operates in a regulated domain, thus all embedded services are regulated and subjected to suitable regulatory framework for data management and exchange. Furthermore, this platform should be perceived as an enabler for new third-parties to explore the open API design to create new services for customers and businesses. The platform provides a replicable configuration, being aligned with standardization strategies for data exchange between energy stakeholders (e.g., IEC 61968) and it is based on ENTSO-E Reserve Resources Processes [44], in what regards to flexibility exchange.

Moreover, it is aligned with EU policy, addressing CEER and Eurelectric recommendations, while covering at the same time the reality of several countries.

As highlighted in Figure 8, the Grid and Market Hub ecosystem comprises multiple external roles from market players connected to the distribution system, TSO, market operator, consumers and other service providers. The stakeholders benefit from Business to Business (B2B) and Business to Costumer (B2C) services available at the Gm-Hub. The platform also establishes a direct cooperation between DSO and TSO, with the market operator as intermediary for the ancillary services market, in terms of flexibility pre-qualification, activation and management. Finally, it also enables the use of local flexibility for technical constraints management, particularly at the low voltage grid level.

Central to the concept for the Grid and Market Hub is compliancy with the latest standards in security, cybersecurity and with the GDPR regulation in terms of data protection compliance.

FIGURE 8 - GRID AND MARKET HUB CONCEPT VIEW.

3.1.2 IDENTIFICATION OF PLATFORM SERVICES AND FUNCTIONS

The adoption of the Grid and Market hub installs a set of B2B and B2C services, adopting a multi-role view for stakeholders to interact with the services. Figure 9 depicts the service naming and structuring, installing a separation between two classes of services, namely: Basic and Advanced services.

Basic services include:

- **Registration**, where users can create a user profile and afterwards enroll in the available services.
- **Authentication**[1], providing means for user validation and grating access to the platform services.

[1] The **authentication** service comprises standard authentication mechanisms to log in into the system for both human (via a frontend application) and machine-to-machine communication with X.509 identity certificates.

- **Download Data**, where consumers can issue data acquisition request to their data from business stakeholders (e.g., metering data from aggregators or DSOs).
- **Share Data**, granting the possibility for third-party data service providers (i.e., data science companies, energy and non-energy data service providers) to request data access to data from consumers. Under the umbrella of the GDPR, consumers are in full control of their data, granting or denying this access at any point in time.

Besides authentication, features such as searching for services or managing the enrollment in services are common to all stakeholders.

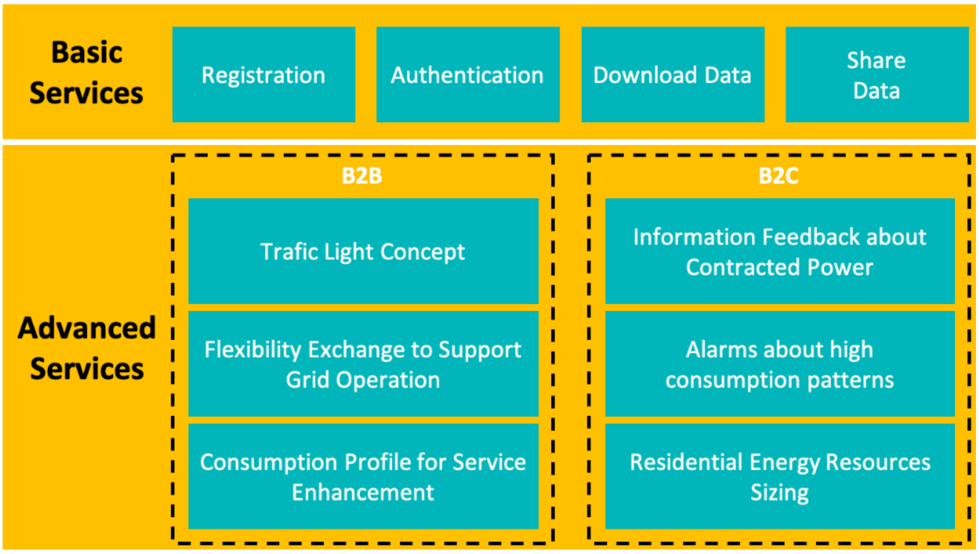

FIGURE 9 - GRID AND MARKET HUB SERVICES.

Advanced services include:

- **Traffic light concept** service, with two main objectives, namely: (a) conduct a technical validation of flexibility for frequency control, activated by the TSO from distributed energy resources connected to the distribution grid; and (b) monitoring of flexibility activation and identification of network areas with frequent limitation in terms of flexibility use (input signal for the DSO planning departments).
- **Flexibility exchange to support grid operation** service, that establishes the exchange of information about available flexibility in the distribution grid per grid user and communicate the pre-book (pre-activation) of the available flexibility to solve technical constraints in the MV and LV grid.
- **Information feedback about contracted power** service, to provide information to the consumer about the usage of contracted power, considering operating grid conditions, season of the year and home energy management system (HEMS) flexibility from intelligent load management functions.
- **Alarms about high consumption patterns** service, which generates alarms to low voltage consumers about high consumption patterns related to excessive electrical energy consumption. The limits and thresholds are defined according to parameters and preferences defined by the gm- hub customer.

- **Consumption profile for service enhancement** service, which enables Energy Services Companies (ESCos) or retailers to uses gm-hub's infrastructure to advertise services to a consumer. The service itself aims to predict the consumption profile of a client to offer value added services that will increase engagement between consumer and retailer.
- **Residential Energy Resources Sizing** service, which enables an ESCo or a retailer to offer a service to a LV consumer for the optimal sizing of residential energy resources. This will include the sizing of storage, PV and water heater.

3.1.3 GENERAL ICT ARCHITECTURE

The Grid and Market Hub architecture is based on a multi-layered software architecture pattern, namely the three-tier design pattern, which relies on a presentation layer (responsible for user interface and user's interactions), an application layer (which handles the business logic and the APIs) and the data layer (which is responsible for storing the application's data). The benefit of using multi-layered software architecture is the independency between layers, in case one technology needs to be changed, causing no impact on the software.

The architecture is depicted in Figure 10. The Grid and Market Hub is developed as a cloud-based application, and it is currently deployed at SAP Cloud. The application benefits from common functionalities such as Identity provisioning and user control and management, together with autonomous and scalable virtual machine instances. Nonetheless, the Grid and Market Hub application can be deployed outside this ecosystem with minimal integration effort as it adopts common interfaces for interaction with common services provided by almost all cloud providers, or even accessible from off-the-shelf software packages for private installations.

All three layers are self-contained and benefit from the cloud provider's infrastructure, which means that the virtualization, resource allocation, security and other infrastructure are handled by the platform provider. The presentation layer is developed as a single-paged web application and deployed as an Angular Hypertext Markup Language (HTML) application. The application layer is developed as a Java web application and is deployed in a Java Web Tomcat server.

The Gm-Hub provides the highest security and quality requirements, regarding the establishment of secure communication channels between stakeholders and the gm-hub. As represented in Figure 10, the communication channels are secured by using TLS protocols. Stakeholders who require access to the business data must authenticate themselves, and their identity must be verified by user and access management.

The application layer, responsible for exposing data and functionalities to other platforms are exposed via RESTFul web services, which are light weight resources, highly scalable and maintainable. In the REST architectural style, business data is considered a resource and is accessed using uniform resource identifiers (URI). The advanced services provided by the gm-hub will consume data using these RESTful APIs, namely the CRUD resources, which are the interfaces for creating, reading, updating or deleting specific objects like service descriptions, service subscriptions. The REST architectural style constrains an architecture to a user/server architecture and is designed to use a stateless communication protocol, typically HTTP, which allows different protocols to be used for the communication between the user and the server.

In terms of the data layer, the Gm-Hub considers a standard relational data modelling strategy to support the application it-self, that is exposed via an ODBC interface towards a RDBMS system (i.e., in this instantiation, SAP's Hana RDBMS is considered), together with cached transient data storage for runtime operations.

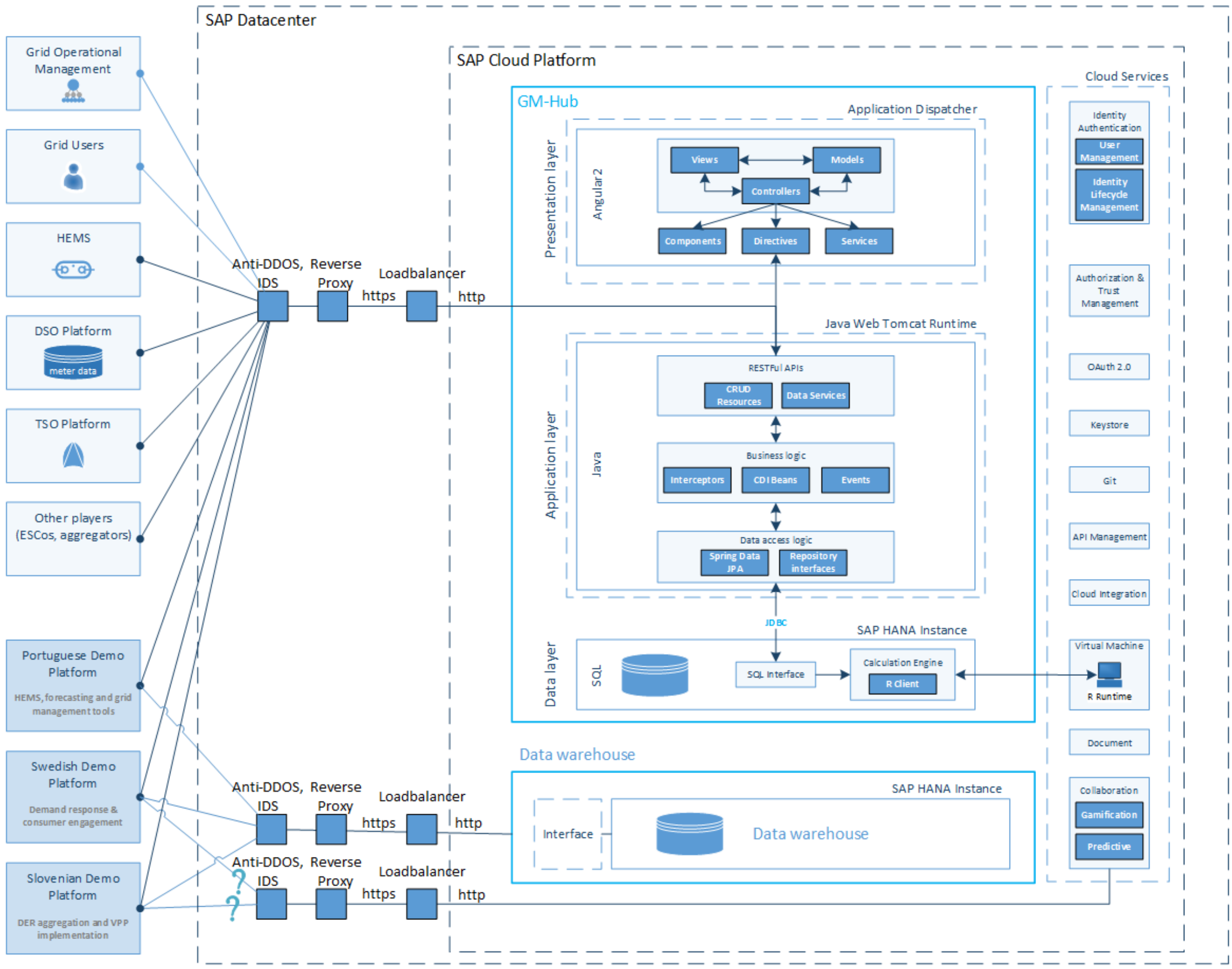

FIGURE 10 - TECHNICAL ARCHITECTURE OF THE GM-HUB.

3.1.4 . DATA EXCHANGE MODELS

The Grid and Market hub platform provides data exchange models that are based in primary formats that vary according to the details of each given service, namely: CIM IEC 61968 for meter data exchange, ENTSO-E reserve resources processes for flexibilities and custom data models for new services.

Gm-Hub services, namely: **download data** and **share data**, manipulate metering data from consumers and exchange it between authorized stakeholders onboarded in these services. For this case, data exchange is modelled per customer as JSON payload. Each data exchange holds a list of readings, where each reading has the signature represented below in Table 10.

Moreover, the platform advanced services such as**: Information feedback about contracted power**, **Alarms about high consumption patterns**, **Consumption profile for service enhancement** or **Residential Energy Resources Sizing**, consume the interface of the **Share Data** service, considering the data model described in Table 10.

TABLE 10 - GM-HUB DATA SHARE SERVICE EXCHANGE MODEL.

Key	Admissible format / values	Description	Encoding	Example
access_code	8 characters	Customer Identifier	UFT-8 string	XXXX1234
z_ts_read	yyyy-mm-dd hh:mm:ss	Read Timestamp	UFT-8 string	2016-01-01 00:15:00
d_register_read	A+	Positive Active Energy	UFT-8 string	
	A-	Negative Active Energy	UFT-8 string	
	FP	Factor of Power	UFT-8 string	
	Voltage phase L1	Voltage in phase 1	UFT-8 string	
	Voltage phase L2	Voltage in phase 2	UFT-8 string	
	Voltage phase L3	Voltage in phase 3	UFT-8 string	
m_read	Double, 9 decimal cases	Value that is read	Double	“4.868871212”
d_read_unit	“kWh” / “%” / “V”	Unit for the read value	UFT-8 string	“V”

Flexibility driven services, such as the **Flexibility exchange to support grid operation** manipulate flexibility data that is modelled in JSON payloads, according to the signature example for representing how a DSO requests flexibility activation in Figure 11.


```
[
	{
		"MessageType": "FLEXIBILITY_ACTIVATION_SIGNAL",
		"SenderID": "sender1",
		"SenderRole": "DSO",
		"ReceiverID": "receiver123",
		"ReceiverRole": " AGGREGATOR ",
		"DistributionNodeID": "bus1",
		"ProducerType": "GENERATOR",
		"OfferType": "SINGLE_BLOCK",
		"Direction": "UP",
		"FlexDeployment": {
			"value": 2.5,
			"unit": "MW"
		},
		"StartDate": "2018-03-26T00:00:00Z",
		"EndDate": "2018-03-26T01:00:00Z"
	}
]
```

FIGURE 11 - DSO REQUESTS FLEXIBILITY ACTIVATION EXAMPLE IN JSON.

3.2 E-FLEX PLATFORM

3.2.1 GENERAL OBJECTIVES AND DESCRIPTION

Enedis has developed E-Flex platform in the context of H2020 InterFlex project, which enables the exchange of information needed to match the supply and demand of a local flexibility mechanism. Aggregators interface their information systems with this platform to post flexibility offers and receive a request for activation if necessary.

The E-flex portal allows aggregators to send potential flexibility needs to certain locations on the grid. Aggregators will then respond with an offer if they have flexibilities in those locations. Once these offers are submitted, the distributor will assess their relevance and effectiveness. It will then be able to request activation from the aggregator, which will then activate remotely at customer's location.

We draw the following lessons.

E-flex has been built to manage the whole flexibility process, except for

- constraint identification (or flexibility need)
- contracts with parties to provide flexibility offers
- the volume calculation activated by parties.

In general, E-Flex worked well for the demonstrator and Enedis uses it as a working basis to integrate the "*flexibility*" object in the IT systems.

Enedis is improving and working to allow manage the flexibility object on 4 axes and IT systems:

- Constraints' Inventory and flexibility need identification.
- topological information & contractual
- Interactions with flexibility service providers (posting offers, reservations, activation & clearing services)
- Providing data for checking calculations & clearing services.

To manage flexibility object concept on its IT systems, Enedis will continue to use its data model based on CIM that has been proven during previous European SmartGrid projects (GRID4YOU, evolvDSO and InterFlex).

Enedis have chosen CIM because:

1. CIM-market is driven by ENTSOE, the TSO at the IEC TC57 with DSO participations.
2. The benefit of relying on CIM is that it is easier to standardize Flexibility object, particularly because CIM is promoted by IEC.
3. The flexibility concept exists and is very near of the flexibility used by some TSO, since 2007, for Balancing and Scheduling in the international interconnexions process and process concerning Electricity Markets and Transparency
4. The modelling of process and object concerning theses process are made on CIM and has become a standard recognized by the IEC, CENELEC, CEN.

5. These standards are used at least since 2007 and are being implemented the Balancing Code, Operational Planning & Scheduling to guarantee the "*interoperability*" between the actor's participating to theses process.
6. The "*local flexibility*" modelized by ENTSO-e & IEC TC57 is not so far of flexibility object need by DSO
7. CIM is known by some actors already working in this process and probably will participate to DSO flexibility process.
8. The use of CIM by DSO will facilitate the "*coordination between TSO – DSO*", when for example one site connected to DSO grid will offer flexibilities to the TSO balancing mechanism & DSO flexibility process. The EU project TDX-Assist has modelized these coordination process with CIM.
9. The Flexibility object used by DSO is very similar to the Flexibility object used by TSO for national mechanisms (the only difference is about the volume measurement unit: TSO works on MW DSO on kW).

The contractual information has not been modelled in E-Flex.

For the future modelling, Enedis is studying different scenarios, according to also art 32 of Clean Energy Package transposition in France. Before entering a contract, you should have identified the constraints, the due date and the use case (deferring network investments, increasing the distribution network capacity, etc.). The constraints identification (constraints' inventory) does not exist yet in E-Flex.

Enedis is also working on the concept of reservation: how to guarantee that actors will be ready for the offer activation. Enedis reinforces the "*flexibility object*" master data reference: particularly states (available, reserved, activated, finalized, realized). This reinforcement will allow to get the flexibility object in the upstream part and in the downstream part and it will allow a better exposure of the "*flex*" object to other IT systems. As part of the demonstrator, the flex object was only exposed to supervision tools. It will be exposed to other systems (calculation, reporting, etc.) in the future.

3.2.2 IDENTIFICATION OF PLATFORM SERVICES AND FUNCTIONS

E-Flex platform was installed at the Regional Control Agency (RMO). As shown in Figure 12 in case of grid constraints, the DSO can call for bids from the aggregators in the event of a flexibility "*need*", to receive flexibility bids and, where appropriate, request their activation.

E-FLEX is a web portal which allows the technician in Control room agency to select grid zones on which he wants activation of flexibilities, to send calls for bids to the aggregators, to view the bids received in return, and finally to choose and request activation of the appropriate bids. Following the user's various decisions, the application sends XML messages to the aggregators.

E-FLEX can also manage geographic areas, which ensures sending to the right aggregator depending on the chosen bid and the associated area. It allows the customers recruited by the aggregators to be managed with their dates of consent to use of their metering data to ensure compliance with the regulations.

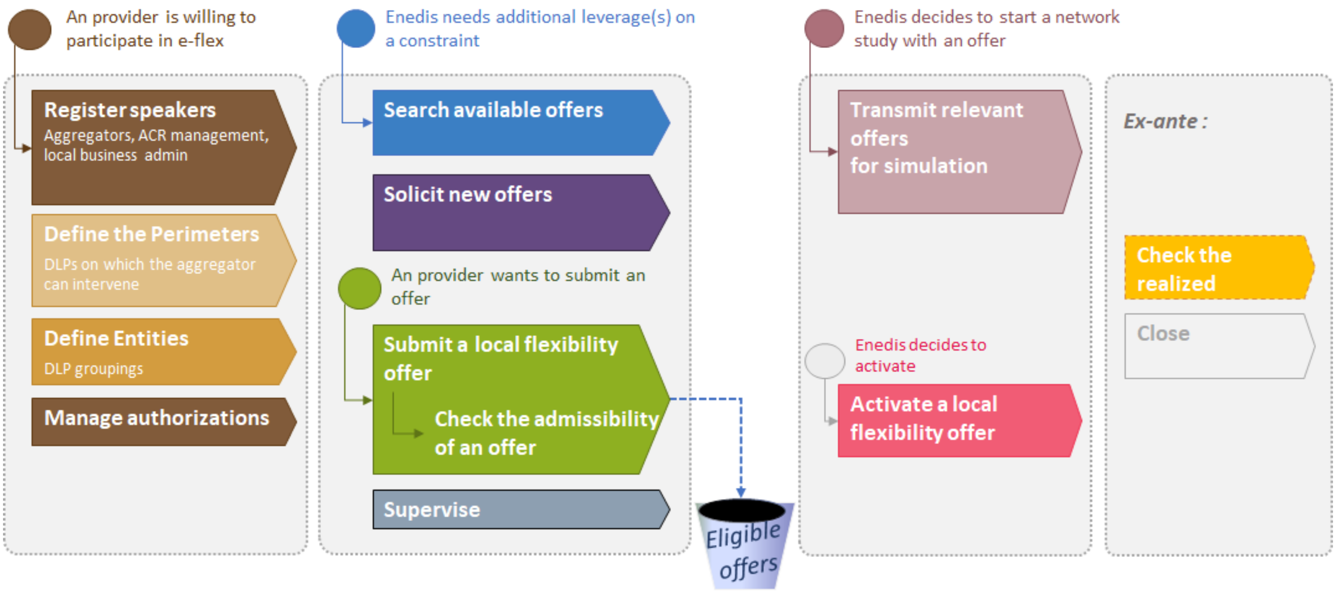

FIGURE 12 - E-FLEX PLATFORM GENERAL FRAMEWORK.

The main services offered by the platform are:

- **Solicitation:** request issued by Enedis to ask aggregators for offers for a given location and period to meet a grid constraint identified by the distributor.
- **Flexibility offer:** proposed by an aggregator to the distributor and relating to an existing entity. It represents the possibilities of modulating the consumption/production of customers belonging to the entity over a given period. The parameters of the flexibility offer are represented in Figure 13.

FIGURE 13 - E-FLEX FLEXIBILITY OFFER PARAMETERS.

- **Request for activation of a flexibility offer**: request sent by the DSO to an aggregator, relating to an existing offer, to activate the flexibility proposed in the offer. Corresponds to the activation request; the aggregator must then, to comply with this request, contact its customers so that the activation is effective. The activation request is a sub-part of the flexibility offer.

- **Aggregator Incapacity signal:** message sent by an aggregator to alert the distributor of its inability to carry out the activation requested and accepted previously.

3.2.3 GENERAL ARCHITECTURE

E-FLEX was developed to be modular, configurable and dynamic in accordance with the needs of future local flexibility markets for which the management of geographic areas and zones may vary.

The steps to be followed to configure E-FLEX for a new local mechanism are as follows:

- Configure a new URL
- Load the database with the new flexibility entities and network substations
- Configure XMPP channels with the aggregators
- Exchange XML Schemas (XSD) with aggregators via the contract to enable them to understand the messages exchanged

As shown in Figure 14, E-FLEX architecture is composed of several Human–computer interaction (HCI):

- Seizure of constraint and request for solicitation
- Offer
- Aggregator management
- PDL management
- Activation request
- Authorization management

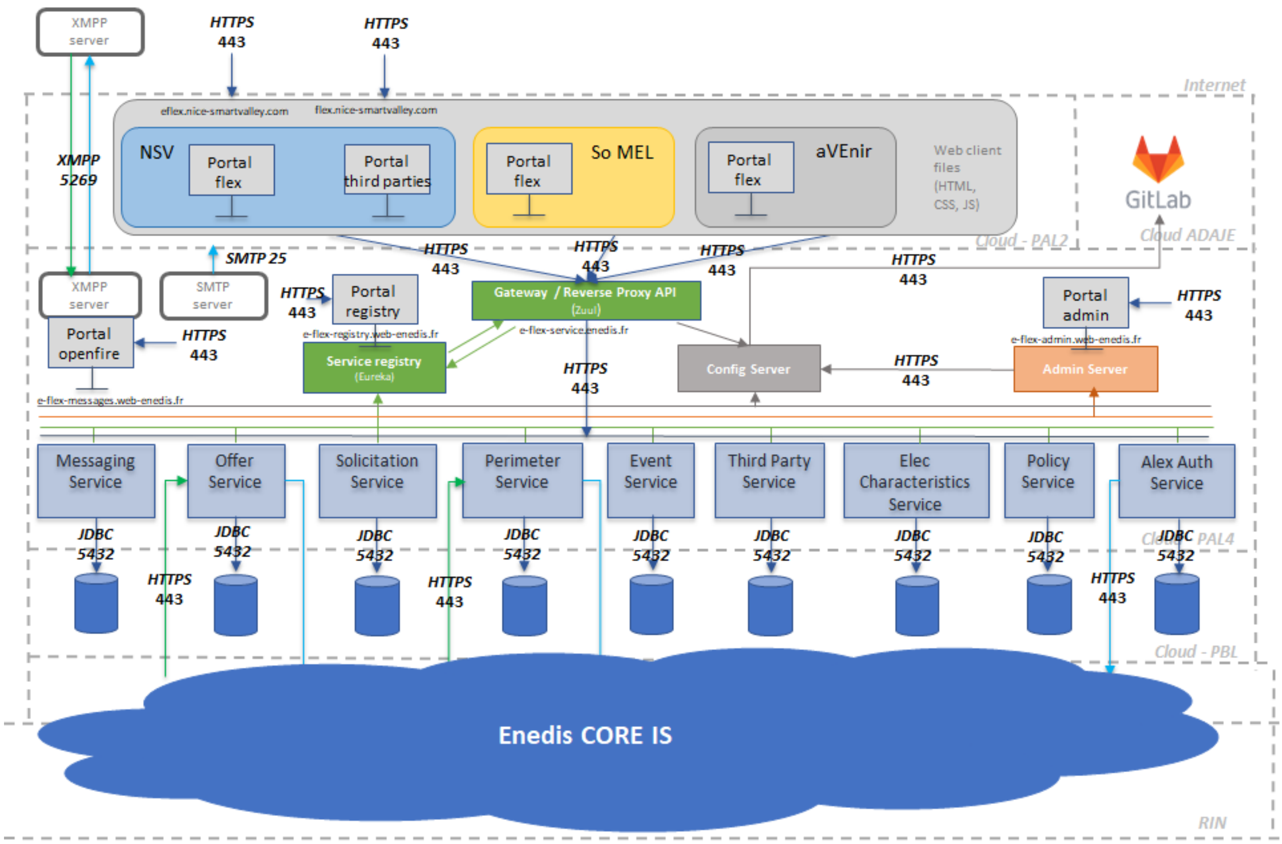

FIGURE 14 - E-FLEX ICT ARCHITECTURE.

3.2.4 DATA EXCHANGE MODELS

E-FLEX is hosted in the Enedis cloud, which is a sufficiently secure environment in which, given their level of sensitivity, the flexibility data can be lodged. XML communications via XMPP channels with the aggregator comply with the CIM Market V2 format (IEC 61970, 61968, 62325), which defines the standards to be complied with in the structure of the XML message transmitted. These standards are communicated to the aggregators in the form of XML Schemas (XSD).

Communication between E-FLEX and the aggregators takes place via XMPP channel. The message sent contains several items of information:

- The relevant entities via a flexibility identifier which represents a single MV/LV substation.
- The time range (start and end dates of a bid).
- The power time series corresponding to the power guaranteed by the aggregator versus time.
- The price of reliability.
- Activation constraints, due to implementation times.

When a new aggregator enters a local mechanism, a log on to the XMPP channel of E-FLEX is necessary to establish communication. The necessary specifications are presented to the aggregator to enable it to configure its channel.

Then, the XML Schemas (XSD) are forwarded to the new aggregators to enable them to communicate with E-FLEX via the XMPP channel. The list of MV/LV substations should be added to allow new customers to be added.

The aggregators, E-FLEX and Enedis interact by exchanging XML messages in CIM Market v1.2 format which is part of the European standard CIM European Distribution Market Profile.

The type of message is always explicitly indicated in the message in the field <MarketDocument> <type>.

This field therefore contains:

- the name of the operation if it is a query
  - Example: <type>Operator Flexibility Offer Request</type> for a solicitation request
- the name of the operation return, if it is a return message
  - Example: <type>Operator Flexibility Offer Acknowledgment</type>, for the return message issued in response to the submission of an offer.

Description of a flex request is presented in Table 11.

TABLE 11 - FLEXIBILITY REQUEST DATA MODEL.

MarketDocument	
mRID	Unique object identification number
revisionNumber	Version number of the object (incremented for each transmission of the same document)
createdDateTime	Date and time the document was created.
type	= *“Operator Flexibility Offer Request“*

	By convention, the type field contains the name of the transaction.
subject	= *"Offer Request"* By convention, the subject field contains the name of the main object Business dealt with in the transaction
<Sender_marketParticipant> **mRID**	Enedis ID
<Sender_marketParticipant> **name**	= *"Enedis" optional*
<Sender_marketParticipant> **roleType**	= *"DistributionSystemOperator"*
<Receiver_marketParticipant> **mRID**	Aggregator ID
<Receiver_marketParticipant> **name**	Aggregator's Name *(optiol)*
<Receiver_marketParticipant> **roleType**	= *"DistributionFlexibilityOperator"*
	Period of time when flexibility is required Rule: Cardinality = 1. expressed in half hours
Domain	Flexibility entity on which an offer is expected to be made Rule : - a solicitation may designate more than one entity. - A solicitation sent to an offeror includes at least one entity.
TimeSeries	Object describing the desired power differences (optional)
Domain	
mRID	the GDO code: code of the structure (e.g. MV/LV substation, MV Client substation) on which the DSO expresses a need for flexibility
name	Name of the Structure (optional)
TimeSeries	
BusinessType	= *"aggregated requested power"*
Measurement_Unit.**name**	*=«KWT»*
FlowDirection.**direction**	*=«A01» ou "A02"*
Period	Object representing the Chronicle of Power
Period	
resolution	*PT30M*
point	Each point describes the time step of the chronicle. Rule: the number of points entered must be equal to timeInterval/resolution.
Point	
position	Sequential value (starting with 1)
quantity	Required power differential

3.3 DYNAMIC COALITION MANAGER PLATFORM

3.3.1 GENERAL OBJECTIVES AND DESCRIPTION

The Dynamic Coalition Manager Platform was developed and piloted in the scope of the H2020 FHP project for the optimal planning and control of clusters of distributed heat-pumps. The platform manages Flex Trading interactions between Grid-Interactive Buildings (prosumers), local grid operators (DSOs) and flex needing stakeholders (BRPs, TSOs). Its objective is to ensure optimal flex activations, for both Implicit Demand Response and Explicit Demand Response business cases, in a local grid-secure manner, leveraging interactions with Building Energy Management Systems.

Grid-Interactive Buildings are characterized by the fact that rather than merely responding to Demand Response incentive signals, either Implicit Demand Response price signals or ad-hoc Explicit Demand Response requests, they engage in an interactive bi-directional Flex Trading dialogue with relevant stakeholders. These may be other Grid-Interactive Buildings with whom they interact for optimal coordination (peer-2-peer energy and flexibility trading), or local grid operators (DSOs) with whom they interact to facilitate congestion forecasting and mitigation, or (technical) aggregators with whom they interact to offer and activate flexibility in a local grid-secure manner i.e. taking local grid constraints into account.

As shown in Figure 15, the Flex Trading interaction scheme consists of an upstream information exchange and a downstream information exchange. The upstream information exchange starts from the Grid Interactive Buildings and contains both the prosumption plan (= baseline: may be either a forecast or the result of a building level Implicit Demand Response optimization e.g. based on tariff structure or price signal) and a flexibility forecast (i.e. capability to deviate from the building-centric optimal plan) as determined by the Building Energy Management System (BEMS). A prosumption plan provided by the building itself, considering the most up-to-date and accurate - including private – information, including building-centric flex activation plans, can be expected to be the most reliable possible for forecasting congestions. The flexibility forecast is used to optimally coordinate among buildings (peer-2-peer energy and flex trading), to determine whether a congestion can be solved by requesting flexibility activations, or to offer aggregated flexibility to flex needing stakeholders.

The downstream information exchange is used to disaggregate an aggregated flex activation request into a per-building flex activation plan. Such an aggregated flex activation request may be issued by the local grid operator (DSO) to resolve a congestion, or it may be issued by a BRP to improve its (forecasted) imbalance position, or it may be determined from an optimal coordination among a cluster of buildings. Using such an optimal disaggregation approach enables a more effective use of the available grid capacity by not needlessly over-constraining a building's dynamic connection capacity and considers each building's specific state and flex activation capacity at the time when the flex activation is needed. Because the Dynamic Coalition Manager leverages the upstream communication stream provided by Grid-Interactive Buildings and does not rely for its forecasts on models and forecasters created from historical data, it does not depend on the availability of such historical data, nor on the existence of a fixed static cluster of buildings and building assets. It is capable to handle dynamic coalitions of buildings and assets, hence the name Dynamic Coalition Manager.

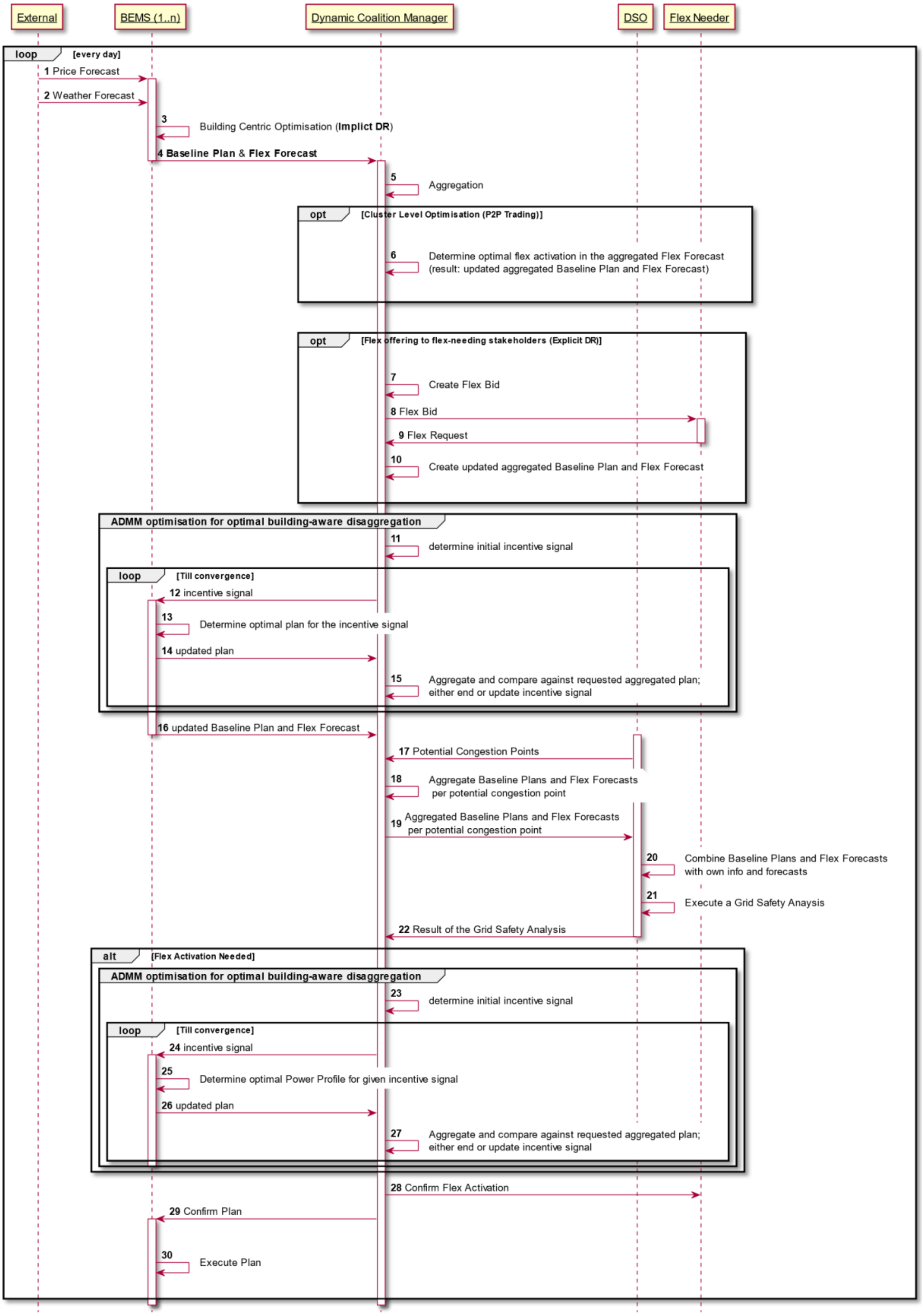

FIGURE 15 - SIMPLIFIED DYNAMIC COALITION MANAGER FLEX TRADING INTERACTION SCHEME.

3.3.2 IDENTIFICATION OF PLATFORM SERVICES AND FUNCTIONS

The Dynamic Coalition Manager platform functionality unites the functionality of numerous roles and stakeholders: (Technical) Aggregator, Energy Community Manager, Peer-to-Peer Trading/Market Platform, etc.

The key functions and services include:

- **Prosumption Profile Forecasting per dynamic congestion point**: the DCM platform provides a prosumption profile forecast resulting from a bottom-up aggregation of prosumption plans (= baselines) provided by Grid-Interactive Buildings. Aggregating information provided by the buildings themselves increases the reliability (and possibly accountability) as it can incorporate the most recent and up-to-date information including impact of building level flex activation plans resulting from building-centric optimizations by the BEMS. These Prosumption Forecasts can be provided to the DSO who can complement this with additional forecasts for non-Grid-interactive Buildings to perform a Grid Safety Analysis and forecast congestions. Aggregated forecasts can be provided per identified potential congestion point if these are known or provided by the DSO. These potential congestion points do not need to be static congestion point, but they can be time-dependent and resulting from (a DSO's) forecasting/risk assessment process.
- **Flexibility Forecasting per dynamic congestion point:** the DCM platform provides a flexibility forecast resulting from a bottom-up aggregation of flexibility forecasts provided by Grid-Interactive Buildings. Aggregating information provided by the buildings themselves increases the reliability (and possibly accountability) as it can incorporate the most recent and up-to-date information including the impact of building level flex activation plans resulting from building-centric optimizations by the BEMS.
- **Grid-secure Peer-to-Peer Energy and Flex Trading for Optimal Coordination among buildings:** the DCM platform can use the aggregated prosumption plans and flexibility forecasts to perform an optimal coordination of the prosumption of the buildings. For this, an optimal aggregated prosumption plan – in relation to a cluster level objective – is determined considering the aggregated flexibility as well as grid constraints if available. These grid constraints can be provided by the DSO, and they can be dynamic (time varying). Such dynamic grid constraints delimit the Freedom-to-Operate for the DCM. This optimization results in a proposed cluster-level aggregated flex activation profile.
- **Optimal disaggregation of an aggregated flex activation profile:** the DCM platform can disaggregate a cluster-level aggregated flex activation profile over the flex providing buildings, considering each individual building's capabilities and limitations. This disaggregation is done by means of an iterative distributed optimization implementation with the ADMM algorithm using (virtual) incentives (shadow prices). The cluster-level aggregated flex activation profile may be the result of a cluster level optimization (optimal coordination), or it may be derived from a DSO imposed (dynamic) constraint. In the latter case, in contrast with traditional traffic light solutions that mostly restrict all buildings in a uniform manner, the DCM disaggregation considers each individual building's capabilities and limitations at the specific time, resulting in

a more effective use of the available grid capacity and a reduced risk of avoidable comfort implications.

- **Grid-secure flex offering for Explicit Demand Response services (TSO/DSO/Prosumer coordination):** the DCM platform can use the aggregated flexibility – possibly after having done a cluster level optimal coordination first – to offer flexibility to flex needing stakeholders e.g. for balancing related purposes (Market Aggregator, BRP, TSO). Hereby, it ensures that only flex is offered that can be activated in a local grid-secure manner, by considering dynamic constraints for dynamic (time-varying) congestion point. The aggregated prosumption plans (per congestion point) can serve as the baseline for explicit Demand Response settlements.

3.3.3 GENERAL ICT ARCHITECTURE

The Dynamic Coalition Manager platform architecture represented in Figure 16 is based on a RESTfull micro-service architecture pattern which contains three micro-services governed by an Orchestrator as main application.

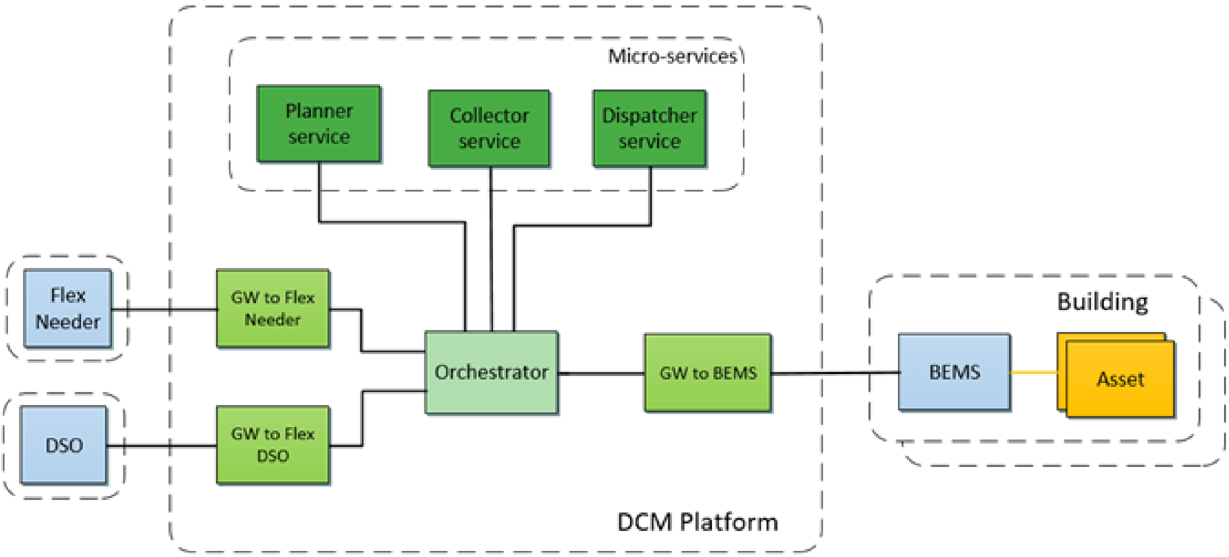

FIGURE 16 - HIGH-LEVEL ARCHITECTURE OF THE DYNAMIC COALITION MANAGER PLATFORM AND ITS INTERFACES TO GRID-INTERACTIVE BUILDINGS, DSO'S AND BRP'S.

The **Collector micro-service** collects the baseline plans and flexibility forecasts that are provided by Grid-Interactive Buildings and creates from this a total aggregated plan and aggregated flexibility forecast, as well as an aggregated plan and aggregated flexibility forecast per DSO (dynamic) congestion point if such information is available.

The **Planner micro-service** determines the optimal aggregated flex activation plan within the aggregated forecasted flexibility. Three optimization objectives, that can be combined, are supported. All of these consider local grid constraints:

- Optimization for a cluster level objective, e.g. collective self-consumption (Peer-to-Peer Trading);
- Offering flexibility to flex needing stakeholders (e.g. to BRPs for portfolio management);
- Using flexibility on request of a DSO to avoid or mitigate a congestion problem.

The **Dispatcher micro-service** disaggregates an aggregated (total or per congestion point) flex activation plan over the flex providing Grid-Interactive Buildings. This does not need to be a static cluster of buildings i.e. the list of participating buildings may vary from cycle to cycle. The disaggregation is using the ADMM algorithm with virtual incentives to determine each building's contribution considering the building's specific capabilities and constraints. This minimizes the flex activation cost, prevents avoidable comfort violations, and makes the most effective use of the available grid capacity.

3.3.4 DATA EXCHANGE MODELS

The Dynamic Coalition Manager platform and the associated Flex Trading interaction scheme serve the same purpose as the USEF interaction scheme: ensuring local-grid secure flexibility activations by explicitly bringing the DSO in the loop, thereby effectively aiming for TSO/DSO/Prosumer coordination. But in comparison with USEF (see Annex 3), the DCM Flex Trading enriches the information exchange with the DSO, and more explicitly defines information exchanges with Grid Interactive Buildings.

At the building interaction side, the DCM leverages the capability of Building Energy Management Systems of Grid-Interactive Buildings to collect more information to inform the DSO, and to increase the reliability of the provided information:

TABLE 12 - DATA EXCHANGE BETWEEN DCM, BUILDING AND AGGREGATOR COMPARED TO USEF APPROACH.

Building to USEF Aggregator	Building to DCM
Not explicitly defined.	**Total prosumption plan** of the active building: i.e. baseline plan incorporating building level flex activations resulting from building-centric optimizations, amended with DCM planned flex activations resulting from both cluster level optimizations as well as activations planned for BRP if any.
	Flex forecast of the active buildings, in relation to already planned activations resulting from the building-centric optimization.

At the DSO interaction side, the DCM provides the DSO with more and more reliable information:

TABLE 13 - DATA EXCHANGE OF DCM WITH DSO COMPARED TO USEF APPROACH.

USEF Aggregator to DSO	DCM to DSO
Only **aggregator flex activation plan** (D-plan): no total prosumption plan. For active buildings, the DSO must combine his own baseline prosumption forecast with the aggregator provided flex activation plan to forecast the total prosumption plan to be used in the Grid Safety Analysis.	Total **aggregated prosumption plan** of (and provided by) the active buildings; **aggregated per potential congestion point** if requested. For active buildings, the DSO can use the provided – and more reliable – information without further manipulation.
No flex information is provided to the DSO: only adjusted aggregator flex activations plans (Flex Offers) in response to DSO Flex Requests.	The DCM provides **information about the available flexibility** (**per potential congestion point**, if requested). Therefore, when the Grid Safety Analysis detects a problem, the DSO can judge immediately from the provided flexibility information whether or not sufficient flexibility is

	available to resolve the problem. And subsequently, better Flex Requests can be formulated that inform the DCM about its 'Freedom to Operate' for activating flexibility without causing new problems.

The DCM creates its forecasts and flex bids not from (models constructed from) historical data. In contrast, they are created from the bottom-up aggregation of information provided by the buildings themselves. This makes them more reliable as they can take into account the best and most up-to-date information and knowledge. Besides, this approach can easily deal with dynamic coalitions of buildings. This means that an aggregation can be done for dynamic congestion points, that it is robust against buildings being removed (permanently or temporarily e.g., because of a communication problem), buildings being added, or building installing or removing assets (HP, EV, Battery, PV, …).

The most relevant information exchanges for the described services and functions relate to time series: (baseline) prosumption plans, dynamic constraints (at dynamic potential congestion points), flex forecasts and flex activation plans. Flex forecasts (and flex activation plans) are modelled as Flex Graphs which resemble power envelopes with a lower and an upper delimiter for the power consumption. These have the advantage of being technology neutral and are easy to aggregate in a scalable manner. All this time series data is modelled in JSON payloads.

3.4 PLATONE PLATFORM

3.4.1 GENERAL OBJECTIVES AND DESCRIPTION

The Platone project proposes an innovative approach for supporting the DSOs and other involved stakeholders in the energy transition phase. Platone aims to enhance the observability of the network and the exploitation of the flexibility for solving both the volatility of renewable energy sources and the less predictable consumption patterns.

The Platone solution consists in a layered set of platforms to meet the needs of system operators, aggregators and end users, named Platone Open Framework. The key components for an open framework are a secure shared data management system, standard and flexible integration of external solutions (e.g., legacy solutions), and openness to external services through standardized open application program interfaces (APIs). All the components of the Platone Open Framework aim to fulfil all these characteristics.

3.4.2 IDENTIFICATION OF PLATFORM SERVICES AND FUNCTIONS

The Platone Open Framework is represented in Figure 17. The components are described below and can work individually or integrated with existing solutions at the DSO.

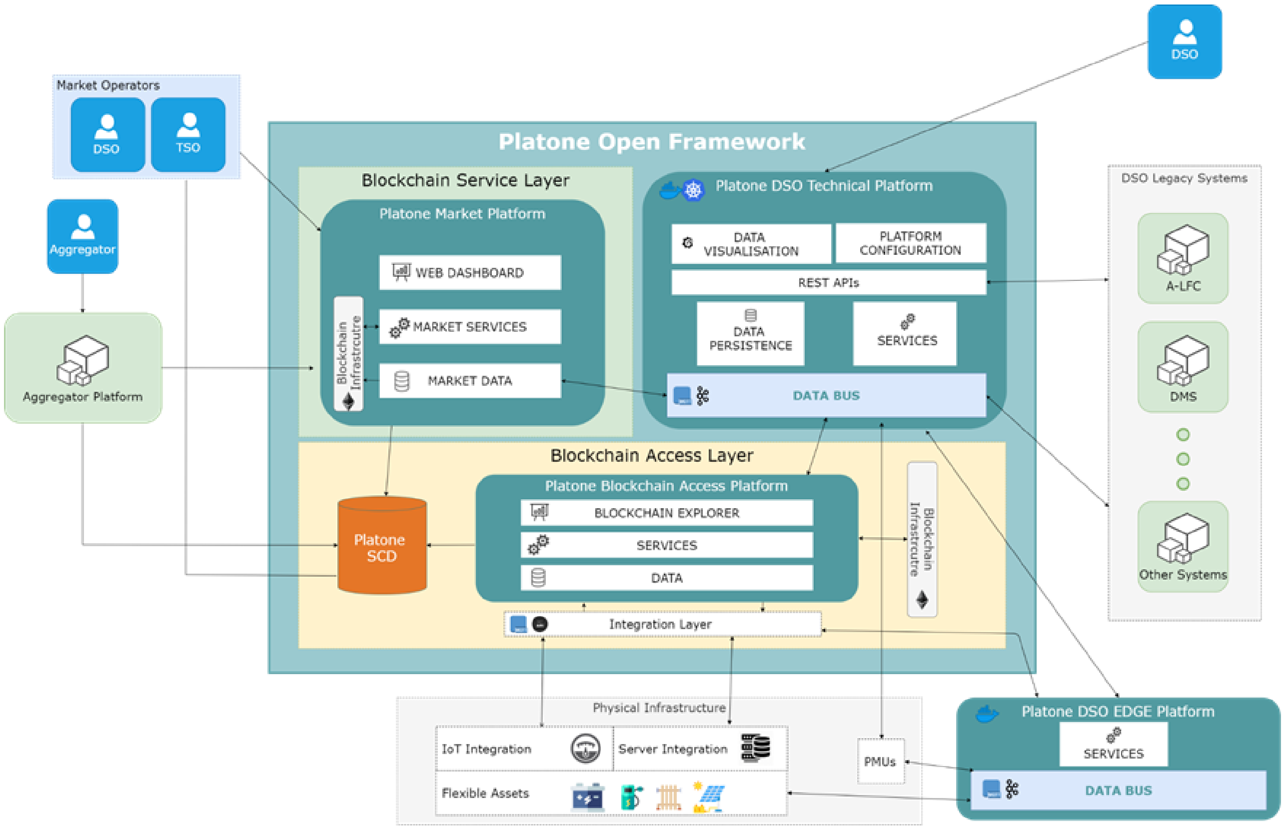

FIGURE 17 - PLATONE OPEN FRAMEWORK [47].

- **Blockchain service layer:** this layer enables the deployment of different blockchain-based components, providing a blockchain infrastructure and Smart Contracts services. In the context of Platone, the Platone Market platform is an example of blockchain-based platform deployed on it.
- **Platone Market platform:** allows the support of wide geographical area flexibility requests from TSOs and local flexibility requests from DSOs. These are matched with offers coming from aggregators resolving conflicts according to pre-defined rules of dispatching priorities. All the market operations are registered and certified within the blockchain service layer, ensuring a transparency, security and trustworthiness among all the market participants. In the services layer the Platone Market Platform implements flexibility services, clearing market tool, and settlement services.
- **Blockchain access layer:** this layer adds a further level of security and trustworthiness to the framework. It is an extension of physical infrastructure and performs multiple tasks, among which the data certification and automated flexibility execution through Smart Contracts. It includes the Blockchain Access Platform and the Shared Customer Database
- **Platone Blockchain Access platform:** implements all the functionalities offered by the blockchain technology through smart contracts and provide an interface for the integration of the data coming from the physical infrastructure.
- **Platone Shared customer database:** contains all the measurements, set points and other needed data collected from customer physical infrastructure. It allows the other components of the Platone open framework to access data in an easy way and without compromising security and privacy.

- **Platone DSO technical platform:** allows DSOs to manage the distribution grid in a secure, efficient and stable manner. It is based on an open-source extensible microservices platform and allows to deploy, as Docker containers, specific services for the DSOs and execute them on Kubernetes. The Data Bus layer included on the DSO Technical Platform allows integration both of other components of Platone framework and of external components (e.g., DSO Management System) with a direct connection to the classical supervisory control and data acquisition (SCADA) system adopted by the DSO served by standard communication protocols [47].

3.4.3 GENERAL ICT ARCHITECTURE

The Platone architecture is blockchain based and builds on the work carried out in the project eDREAM. Platone will evolve, adapt and upscale the eDREAM open blockchain hybrid architecture, which can be deployed on top of a variety of flexibility devices and can be integrated with stakeholders' legacy platforms (for instance internal systems of aggregators or DSOs).

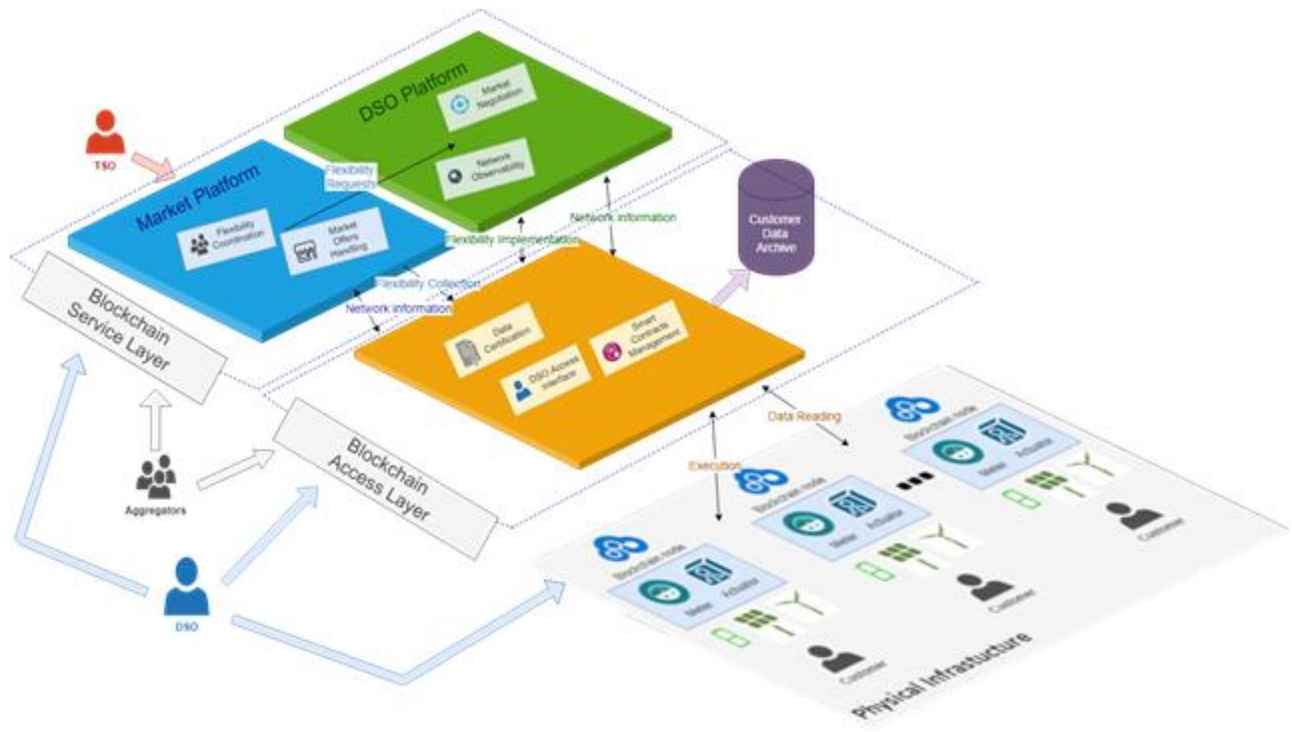

FIGURE 18 - PLATONE PLATFORM ARCHITECTURE [46].

In the case of the Platone DSO Technical Platform, the platform design builds on previous work done in the Horizon 2020 project SOGNO [48] and relies massively on a micro-service architecture. The presented platform architecture aims at facilitating the transition to modular, micro-services-based control centre software solution for distribution system operators. This allows for faster adjustment and independent development of components. The goal is to provide system operators and automation software developers with an open-source framework that exposes open APIs to plug in new automation functions and supports industry standards such as CIM IEC61970 and IEC61850.

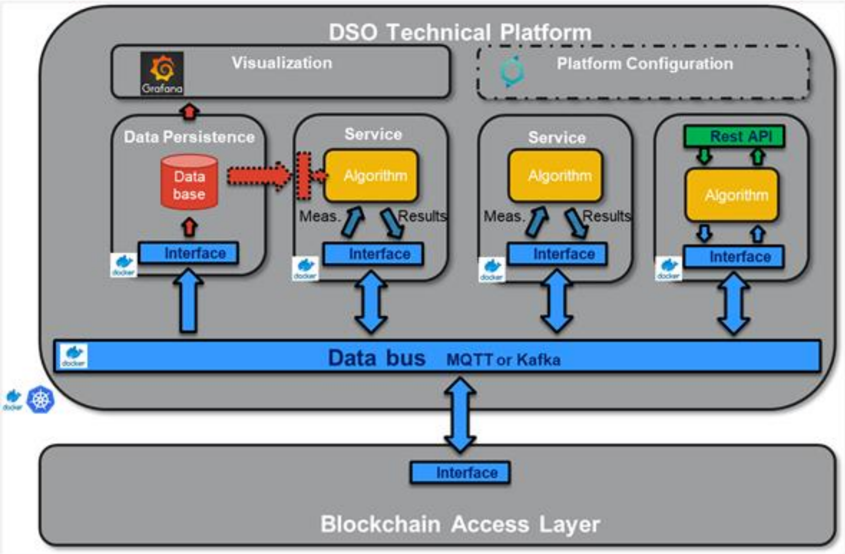

FIGURE 19 - DSO TECHNICAL PLATFORM AND INTERFACE WITH BLOCKCHAIN.

To address requirements such as high availability, scalability and modularity from the very beginning, the DSO Technical platform is designed for deployment on Kubernetes [49] clusters. Kubernetes, also known as K8s, is an open-source system for automation deployment, scaling and management of containerized applications. As all microservices of the platform are per requirement containerized in Docker [50] containers, they can easily be deployed on a Kubernetes cluster. Kubernetes also simplifies different deployment approaches: from edge- and public-cloud to on-premises installation. However, the on-premises installation is considered the most relevant for a control centre platform.

In order to minimize initial hurdles, Platone provides detailed installation manuals for a local installation based on the lightweight Kubernetes distribution k3s. The Databus is one of its core components and is implemented by means of a message broker to which all services can publish and / or subscribe in order to exchange data with other services, with field devices, or with external systems. Field devices or external systems can be made available in the data bus either directly or through the Platone Blockchain Access Layer [51].

With regards to the Platone Market Platform (see Figure 20), it consists of a three-layer architecture namely: an UI layer which includes a web dashboard that allows market players to manage their own markets operations, as well as permits the handling of the Market Platform features. The Service layer covers the business sphere; namely the markets clearing tools, the flexibility services, the settlement namely and the smart contract services. The third layer is the data layer which provides the management of the market data and as well as covers registration of the market operations within the blockchain infrastructure. Depicted on the right side, the blockchain services layer enables the deployment of smart contracts the infrastructure of the layer is based on Ethereum blockchain nodes. In addition, the communication layer depicted on the left side permits the integration of external components along the different layers of the platform. The Communication Layer covers both synchronous communication, which is implemented in the API Gateway via REST APIs, and asynchronous communication which is implemented in the Message Broker [54].

The Platone Market Platform exists as a virtual flexibility market space where market parties can participate in different market sessions. Before a market session begins, the Market Platform receives the network configuration. Under the session the Platform receives flexibility offers and requests by the market participants. Finally, at the end of a market session, the Platone Market Platform performs the economic phase relates to the market clearing, namely the matching of the offers and the requests [54].

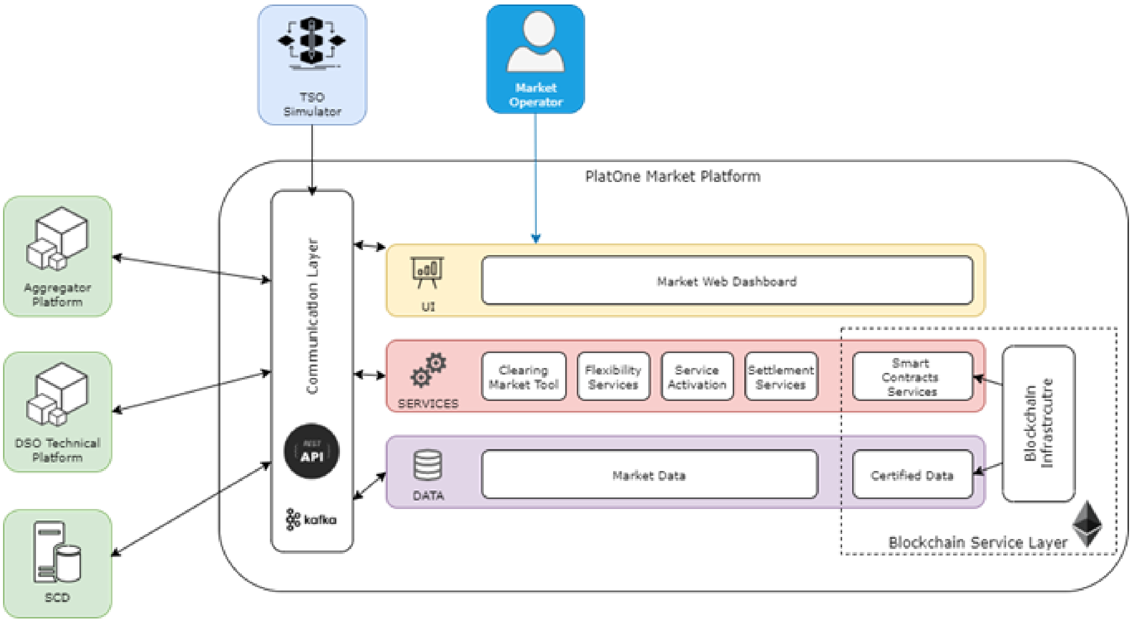

FIGURE 20 - PLATONE MARKET PLATFORM ARCHITECTURE.

3.4.4 DATA EXCHANGE MODELS

The data exchange in the Platone Architecture is based on the SARGON (SmArt enerRGy dOmain oNTtology) Model which extends the SAREF to cross-cut domain-specific information representing the energy domain [52]. It was developed by looking into existing standards in the energy domain and is powered by smart energy standards as well as IoT initiatives and real uses cases. In the Platone Market Platform specifically, the data models follow the Open API specification [53].

3.5 COMPARATIVE ANALYSIS

The overviewed platforms have all a common goal, which is to facilitate the market participation and the use of flexibility from distribution network consumers/prosumers. It can be seen however, that different approaches are taken to this end, namely regarding the objectives, services provided and architecture.

Regarding the platform's objectives, we would like to highlight two main goals, aligned with DSO expected roles:

- Market Neutrality, ensuring universal access to consumers and DER, being technology agnostic and enabling new business models and flexibility trading. All platforms enable the integration of flexible resources for grid support purposes, both implicit (price responsive) or explicit flexibility (mostly through bilateral contracts or market based).
- Transparent access to information and data handing, providing smart metering information in a non-discriminatory manner and with the consumer's consent, to the retailers (market players) for billing purposes, as well as to other stakeholders like energy services companies

(ESCo). It also includes system data required to facilitate FSP provision of services, considering the different processes involved (e.g., grid flexibility zones and needs, requests and offers management, validation and settlement, etc.).

While E-Flex and DCM are more focused on enabling flexibility integration in distribution networks and energy communities, both Platone and Gm-Hub propose a framework providing services to the smart grid ecosystem as an all, providing specific services for consumers, aggregators, and data service providers. The main difference relies in the architecture: Gm-Hub follows a centralized approach that allows for multiple stakeholders to be connected to the same platform (including multiple DSOs), while Platone follows a decentralized approach, enabling the interaction between different platforms with different technologies.

Regarding services, as shown in Table 14 all platforms include flexibility related services. Even though this is a common function to all platforms, they have different steps to tackle the exchange of information. E-Flex platform for example, makes a clear distinction between the flexibility request (solicitation), flexibility offer, and request for activation stages. The platform even goes beyond the grid support, foreseeing also a "*grid-secure Peer-to-Peer Energy and Flex Trading for Optimal Coordination among buildings*". GM-hub pays special attention to the data handling, namely considering GDPR requirements and it facilitates the implementation of additional services to be provided by external stakeholders. It does so, as it complements the platform's functionality with non-energy related services such as i) consumption profile for service enhancement and ii) residential energy resource sizing. Platone on the other hand makes use of its data shared database, for allowing other components of the Platone open framework to access that data.

TABLE 14 - IDENTIFICATION OF THE MOST COMMON PLATFORM SERVICES (ENERGY AND NON-ENERGY).

Services/Platform	Description	Gm-hub	E-Flex	DCM	Platone
Explicit security and access features	Provided by features adding security and trustworthiness such as the blockchain access layer, registration, and authentication functions.	x			x
Data handling services	Data collected from customer physical infrastructure, which can be downloaded, processed and shared.	x			x
Flexibility offer/bid matching related services	All features related to flexibility exchange to support grid operation (and peer-to-peer trading), including offering, request and potential activation according to pre-defined rules.	x	x	x	x
Reporting and alarms signalling capabilities	This feature refers to hierarchically reporting of alarms such as high consumption patterns, aggregator incapacity or the connection to classical supervisory control and data acquisition systems	x	x		x
Consumption forecast, profiling and dis/aggregation services	This function includes flexibility forecasting, optimal disaggregation of an aggregated flex profile, technical validation of flexibility and consumption profile for service enhancement	x		x	
Enhanced services or communication registry	Allows for implementation of several functionalities offered for example by blockchain, feedback information regarding contracted power. Includes also residential energy resources sizing	x			x

Platform architecture and interface approach

Regarding relevant approaches towards the platform architecture and interface with the external stakeholders, the overviewed platforms have common approaches and distinct characteristics.

- The GM-Hub is based on a multi-layered software architecture pattern. It proposes three layers i) a presentation layer which is where the interaction with the user takes place, ii) an application layer which is a trading or business environment layer including the necessary logic in it, iii) and the data layer.
- E-FLEX foresees a modular approach, allowing the integration of future local flexibility market's needs. It’s a cloud-based system containing all services, which uses an API and gateway to contact with external actors. It is a server client approach where external parties need to register and a normal administrator privilege access for configurations. The web platform may have different UI depending on the registry/privilege (actor) profile and role.
- The DCM proposes a micro-service architecture pattern, coordinated by an orchestrator module. This module interacts with the external stakeholders through dedicated gateways towards the DSO, the Flex needer and the BEMS. The micro-services are described as the planner, collector and dispatcher modules. It is a closed solution in the sense that it serves a specific purpose, where the accesses and roles are defined from the beginning.
- The Platone architecture is blockchain based and can be integrated with stakeholders’ legacy platforms and foresees a modular/incremental approach. Similarly, to the DCM platform it also proposes an architecture based on micro-service architecture pattern. It resembles the GM-Hub as it defines three similar layers, I) a web platform to interact with the market operator to manage their own markets operations, ii) a service layer covering the trading activities namely the markets clearing tools, and iii) a data layer providing management of the market data as well as covers registration of the market operations. All these three layers are integrated into a communication layer which is in fact the main channel of communication with the TSO, aggregators, DSO platforms and SCD.

Platform Modelling approach

Regarding the modelling approaches also distinct and similar features can be found:

- GM-Hub provides data exchange models based on CIM IEC 61968 for meter data exchange and ENTSO-E reserve resources processes for flexibilities and custom data models for new services. It manipulates data in JSON format.
- Similarly, E-Flex complies with CIM Market V2 format IEC 61968 and specifies the IEC 61970 and IEC 62325 standards. These define the structure of the XML message format used for messages.
- Regarding the DCM platform, it builds upon the USEF approach, serving the same purpose and uses the JSON format for the data modelled.
- Platone on the other hand follows a different ontology, SARGON, characterized in Chapter 5 (see 5.1.5).

A comparative analysis was required to identify what aspects could be replicated in the DSO interface and what novel features will be implemented. The work done on standards was extensively covered and will be used in the development of the Interconnect DSO interface. Further analysis is depicted in chapter 5 of this document.

3.6 POSITIONING OF DSO INTERFACE AND INNOVATION POTENTIAL

Regarding replicated aspects, the DSO interface will adopt an aligned approach:

- With standardization strategies for data exchange between energy stakeholders (e.g., IEC 61968).
- The interface also complies with the GDPR regulation in terms of data protection (anonymization service and user data as an example).
- Regarding the data exchange, this will very much be based on CIM, similarly to the approach of the Gm-Hub, E-Flex platforms. However, having in mind interoperability and efficient use by stakeholders, it will bridge CIM with elements of the other information models such as Flex-Offer and USEF acknowledging their contribute to flexibility.
- Decentralized and modular approach to service use and development
- The contacts with external actors/services will be enabled by using a set of APIs which can also be found in the E-Flex platform.

Moving on from the replicable features of past work, the DSO interface adds to previous platforms in different ways. These can be described as follows:

- An approach inspired on the enhancement of services will be adopted in Interconnect. The DSO Interface will innovate in integrating the observability services, taking stock of the full potential of the low voltage advanced metering infrastructure and HEMS, generating useful knowledge from decentralized information. It makes particular use of the HEMS as both single and collective elements, where cross check functionalities and aggregated data add value to the network analysis.
- Moreover, the dynamic tariff scheme, for example from the German pilot, also presents an alternative approach, highlighting this next generation tool that is the DSO Interface.
- Another innovative aspect is the use of a service market store, where a list of APIs corresponding to the different services access will be developed. This ensures replicability and a modular approach to identify, include, replace, modify and add services. It also enables a decentralized access to the services requested, as these may run locally or remotely on virtual machines.
- Regarding data exchange it takes stock of the best practices of different approaches as it combines features from CIM, Flex-Offer and USEF depending on the application. A more detailed analysis of applicable information models is provided in Chapter 5.

Further specifications of the interface are now possible and will be introduced in the following chapters

4. FUNCTIONAL SPECIFICATION OF THE DSO INTERFACE

This chapter presents the overall concept of the DSO Interface, its high-level architecture, potential services and data models. The DSO interface concept was developed as part of Interconnect's smart energy reference architecture [71], to ensure a standard interaction between DSOs and energy and non-energy marketplaces, ensuring neutral, transparent and secure data access to all market players.

The DSO interface will enable the demonstration of InterConnect use cases (see Table 1) adopting a standard and replicable interface with the DSO from the different pilots. The main objectives of the platform are the following:

- Allow universal access of DER, microgrids and energy communities to flexibility and energy markets, considering different flexibility market models (including P2P markets).
- Accommodate flexibility services designed according to the needs of the DSO
- Compliance with GDPR
- Cybersecurity

The concept was developed to respond to the different Interconnect use cases involving the DSO (see Table 1), considering existing frameworks for flexibility integration (see Chapter 2) and considering other relevant flexibility integration interfaces (see Chapter 3).

4.1 IDENTIFICATION OF ROLES AND SYSTEMS

From the analysis of the use cases in Table 1, we identified the actors and systems which interact with the DSO as shown in Figure 21 and detailed in Table 14. The systems were then grouped by the actors previously in Chapter 2 (see section 2.1) to which they can be associated, as represented in Figure 22 and detailed in Table 24.

For example, smart metering infrastructure is operated by the MDO or this role can be performed by the DSO. Similarly, Flexibility market or procurement platforms can either be operated by a neutral market operator or by the DSO.

Within the DSO domain, the DSO Interface will need to interact with internal systems, namely:

- **IT corporate systems**, to ensure secure connectivity with external stakeholders, while maintaining the security of the internal systems.
- **SCADA/ADMS**, the main system involved in the operational planning and real-time operation of the distribution network. ADMS will need to support the flexibility framework adopted, namely the predictive management applications capable of defining flexibility needs, select offers and validate market-based solutions, aligned with the processes involved (see 2.3.2).
- **Outage Management System (OMS),** supporting fault location-based on real-time data from SCADA, AMI and consumers complaints. In the case of InterConnect, it can also benefit from external services related with the processing of connectivity information from BEMS and EMS.
- **Regulation and planning departments and software**. Regulation and planning department are responsible for the computation of dynamic tariffs and computation of long-term flexibility requirements and the definition of the areas of the network requiring flexibility or able to provide the required flexibility (e.g., flexibility areas, congestion nodes, etc.)

- **Advanced metering infrastructure**, in the cases the DSO is also the Metering data operator (MDO). In this case, the smart metering information collected will be processed for grid operation, for settlement, for consumer awareness and for external stakeholders interested in providing flexibility services.

TABLE 15 - DESCRIPTION OF SYSTEM SCOPE AND MAPPING OF RELATED ACTORS.

System/Device	Actor	Scope
Smart Meter	Metering Data Operator DSO	Remote reading and processing of metering and grid information (e.g., load and voltage profiles, active and reactive energy consumption, voltage, outages, etc.)
Flexibility Platform	Neutral Market Operator DSO	Depending on the flexibility framework adopted (see section 2.3), this ICT platform ensures: the registration of flexible resources and aggregators to provide flexibility offers, pre-qualification (optional) market operation, delivery and settlement. Depends on the explicit flexibility defined and market models. It can also be used for bilateral contracts (see USEF framework in and gm-HUB)
Flexibility aggregation platform	Aggregator/ Retailer	ICT platform responsible for the management of flexibility resource portfolio that can include a single type or a combination of flexible resources. It interacts directly with the flexibility providers (homes, buildings, RES plants, microgrids, etc.) collecting data and activating flexibility when necessary.
Data Service Platform	Data Service Provider	Entity that can host data driven services for data collection from the flexible resources.
Energy Community Management platform	Energy Community	ICT Platform to support an energy community, often established within a regional boundary, to facilitate P2P trading, local optimization (often in the context of sustainability) and interaction with external stakeholders (DSO, Aggregator/Retailer, etc.).
Dynamic Coalition Manager Platform (DCM)	Aggregator Energy Community Manager, Peer-to-Peer Trading/ Market Platform	Its responsible for calculating the baseline, forecasting the prosumption profile and the individual (building) and aggregated (e.g., at community level) flexibility. It can also compute an optimal coordination between buildings, either to improve their overall operation at the community level, or to provide flexibility to grid or market operation.
Smart Orchestrator	Consumer	IT solution that collects and stores real-time and historical data through the Interconnect interoperability layer from energy retailer, flexibility platform, appliance manufacturer, smart metering and EV data platform to provide home/building/communities with optimal energy management aiming to minimize energy related costs and maximize renewable self-consumption.
Home/Building Energy manager/Control Box	Consumer	IT solution that collects information from home/building sensors and smart meter, through the Interconnect interoperability layer, integrating from basic energy monitoring services to more advanced optimal energy management services, enabling also the interaction with external systems and actors (energy communities, aggregator/retailer, DSO, etc.). It can also include a simpler interface to implement control signals form.

FIGURE 21 - USE CASE ACTORS AND SYSTEMS INTERACTING WITH THE DSO.

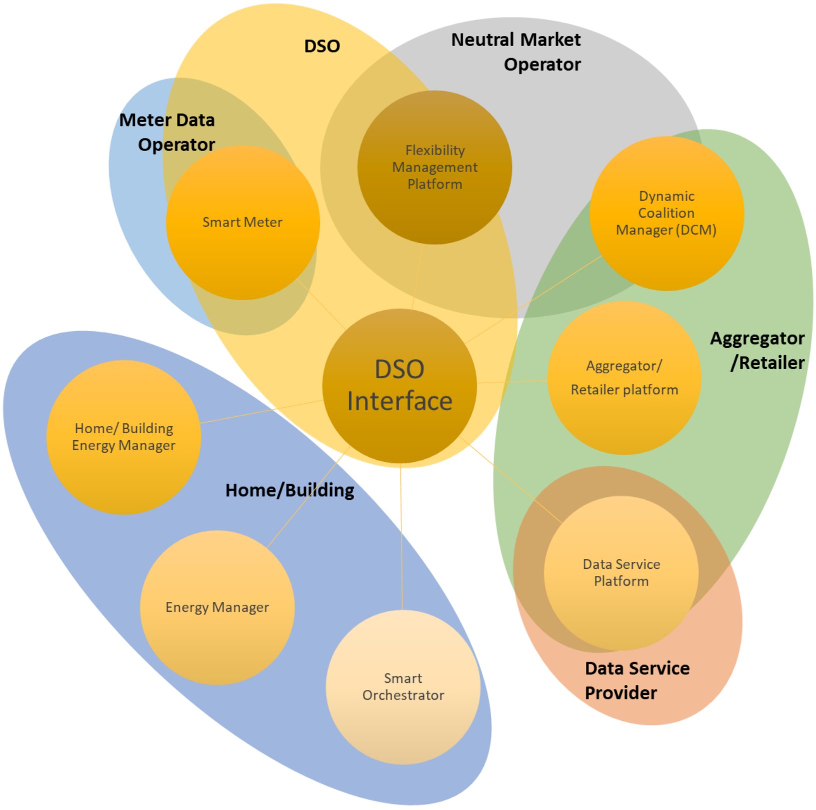

FIGURE 22 - MAP OF ACTORS' SYSTEMS.

Figure 23 shows the interactions of DSO within Interconnect ecosystem, considering the analysis of InterConnect use cases (see previous section 4.1). Within InterConnect pilots, the DSO will assume the roles of the Metering Data Operator (MDO) and, to some extent, the role of the Neutral Market Operator, considering that the DSO will interact directly with the aggregator for the provision of flexibility services, being responsible for managing all the processes involved in flexibility procurement. The roles were left separate to ensure compatibility with different flexibility procurement frameworks adopted.

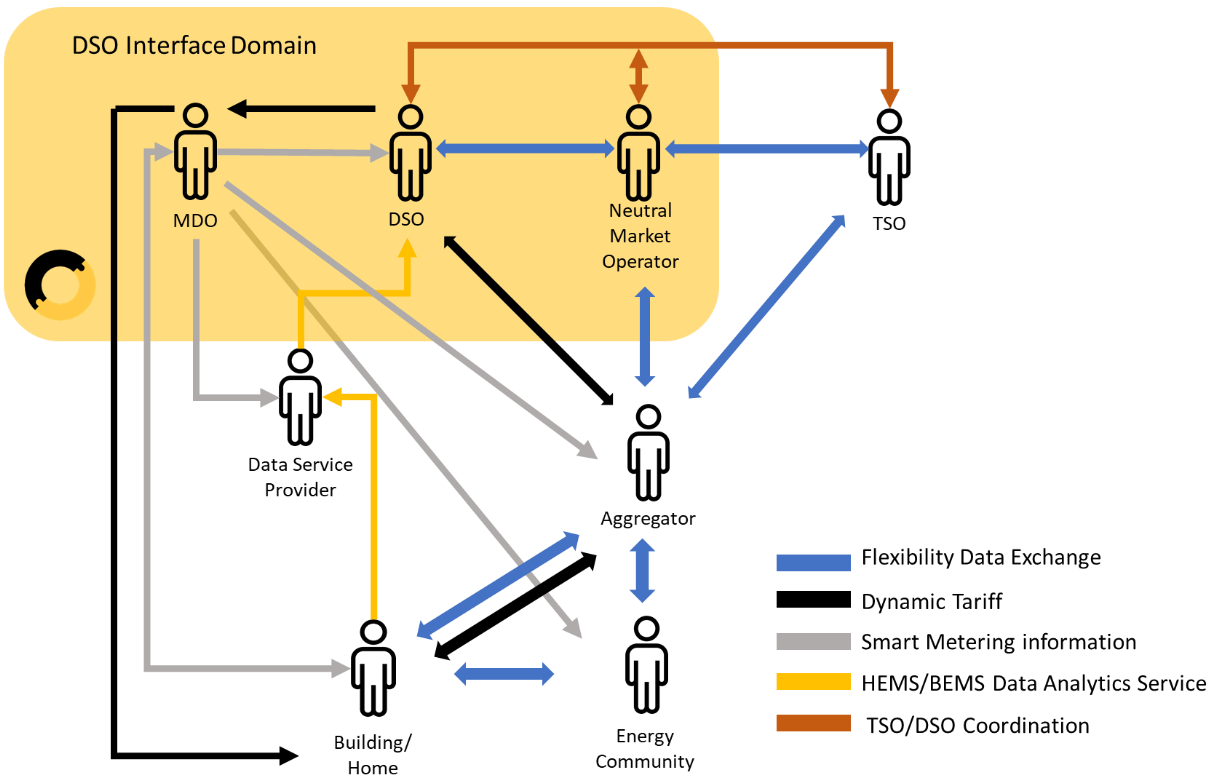

FIGURE 23 - ROLE MODEL OF THE DSO INTERFACE.

4.2 DSO INTERFACE GENERAL ARCHITECTURE, SERVICES AND DATA EXCHANGE

The DSO interface is a digital interface that allows the data exchange between DSO and other stakeholders, namely for enabling flexibility grid support services. The DSO interface will integrate a set of adapters, allowing it to become interoperable and integrate with the IFA. The DSO Interface will be supported by a platform running several core services for data exchange, translation, and processing.

The DSO Interface will assume a centralized architecture, similarly to the platforms analyzed in Chapter 3. It's integrated within the InterConnect Framework[2] (IFA) from the smart energy reference architecture designed in WP2 [71], enabling interoperability and replicability between smart grid

[2] InterConnect Framework: A collection of tools enabling interoperability and the intelligent interaction of many devices and services from different domains (e.g., home automation, energy management, etc.)

domain, smart building/home and non-energy service domain (e.g., data analytics services offered within the service marketplace).

The simplified version of the IFA is depicted in Figure 24. To support the provision of interoperability, several tools are required to enable semantic data exchange, and to support operation, making the available set of service and capabilities in each digital platform visible.

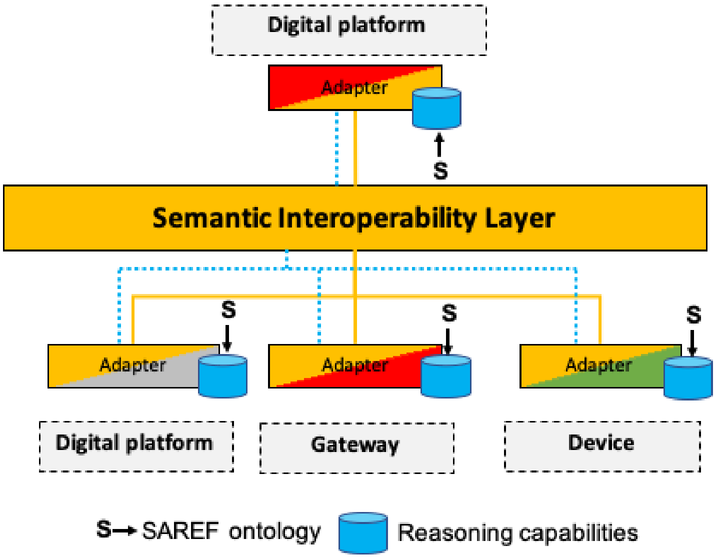

FIGURE 24 - INTERCONNECT INTEROPERABILITY FRAMEWORK.

The provision of interoperability is based on the concept of "*Adapters*" that allow the necessary adjustments and become the gateway towards the ecosystem of interoperable services. *"Adapters"* will be **integrated into digital platforms, gateways, standalone services, or devices**. They will be based on a **generic adapter model, that will then extend a set of common ground functionalities to specific adapters**, distinguished based on the underlying native technologies for transport and execution.

The DSO interface architecture is represented in Figure 25. It builds a gateway between DSO's legacy systems for IT&OT operation and other relevant actors, such as: Aggregators, Data Service Providers and ultimately with consumers (see Figure 23).

The DSO interface is composed of the following building blocks:

- InterConnect generic adapter(s), providing the interface between DSO's core-services (discussed in 4.2.2) and external stakeholders within IFA. When incoming data requests arrive at the adapter, they are routed to one of the specific core service controllers available, that then bridge with the DSOs OT systems.
- DSO Interface data exchange and management services platform, responsible for the data management, aggregation according to the specificities of the services and also for the necessary data translations between interoperable data that arrives from the ecosystem and specific data formats e.g., CIM, IEC 61850. The same happens for the inverse scenario when data originates at the DSO interface and is forwarded to other stakeholders.
- Interface towards internal IT and OT systems and authentication and access control mechanisms.

Therefore, the DSO interface considers two interfaces, namely a north-bound interface towards the Interconnect Interoperability Framework and, a south-bound interface towards internal DSO IT and OT systems. The north-bound interface adopts the interoperable interface of the adapter to export the core service API's. It is capable of mediating data exchange with other stakeholders, while the south-bound interface is capable to interact with legacy system and grid assets at the level of the DSO. The north-bound interface is bounded by the Interoperability Framework's semantic interoperability and interface compliance requirements.

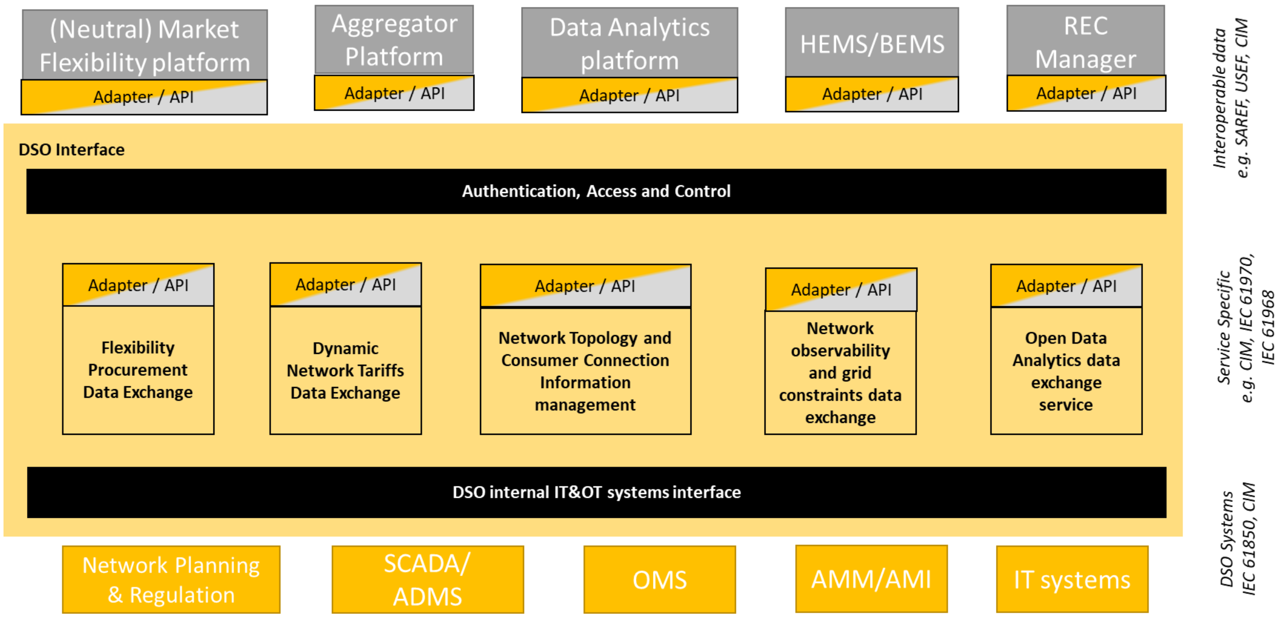

FIGURE 25 - DSO INTERFACE HIGH-LEVEL ARCHITECTURE.

Figure 26 represents the internal structure of the DSO Interface and how it communicates with external entities. InterConnect adapters will be adopted for the interaction with external actors. However, to maximize replicability, the DSO interface also foresees the use of Restful API services. A more comprehensive view on the modules that compose the architecture can be found in Table 16.

4.2.1 COMMUNICATION MIDLEWARE

The communication middleware (Figure 27) is a core module to enable external interactions. It serves as the middleware between the operational modules, or south-bound, responsible for the data processing and availability from the DSO side, and the services that the external entities make available for DSO consultation (north-bound). As depicted in Figure 27, it will have two distinct working modes in terms of communication: through Restful APIs, by both exposing the services' APIs and routing the DSO interface own requests to the necessary endpoints, and by using the Generic InterConnect Adapter, developed in WP5, together with an Service Specific Adapter (under development), which will handle the proper conversion of the REST services to the InterConnect Generic Adapter and therefore ensure the compatibility and integration with IFA.

By following this approach, each internal DSO service will just have to perform/receive requests to/from the communication middleware, and the service middleware inside it will make the necessary message adaptations and routing.

TABLE 16 - DSO INTERFACE FUNCTIONAL MODULES

Modules	Functions
Communication Middleware	- Authentication / Authorization / Registration / Access Policies Management - Message Adaptations - Requests Routing - Interconnect semantic interoperable layer connection
Developer Portal	- API Documentation & Versioning
Flexibility Management Platform	- Flexibility procurement related activities
Running Services	- Network Observability and Grid Constraints - Dynamic Network Tariffs - Open Data Analytics - Network Topology and Consumer Connection
Data Storage	Set of relational databases, to serve as storage for: • Running modules related data • Metering data • Advanced analytics data
Analytics Engine	Data retrieval, aggregation, and visualization
DSO OT Data	Storage for structured and unstructured data from DSO internal OT Systems, namely metering and grid data.
Advanced Data Processing	Dedicated infrastructure to perform advanced analytics through ML algorithms, forecast data,

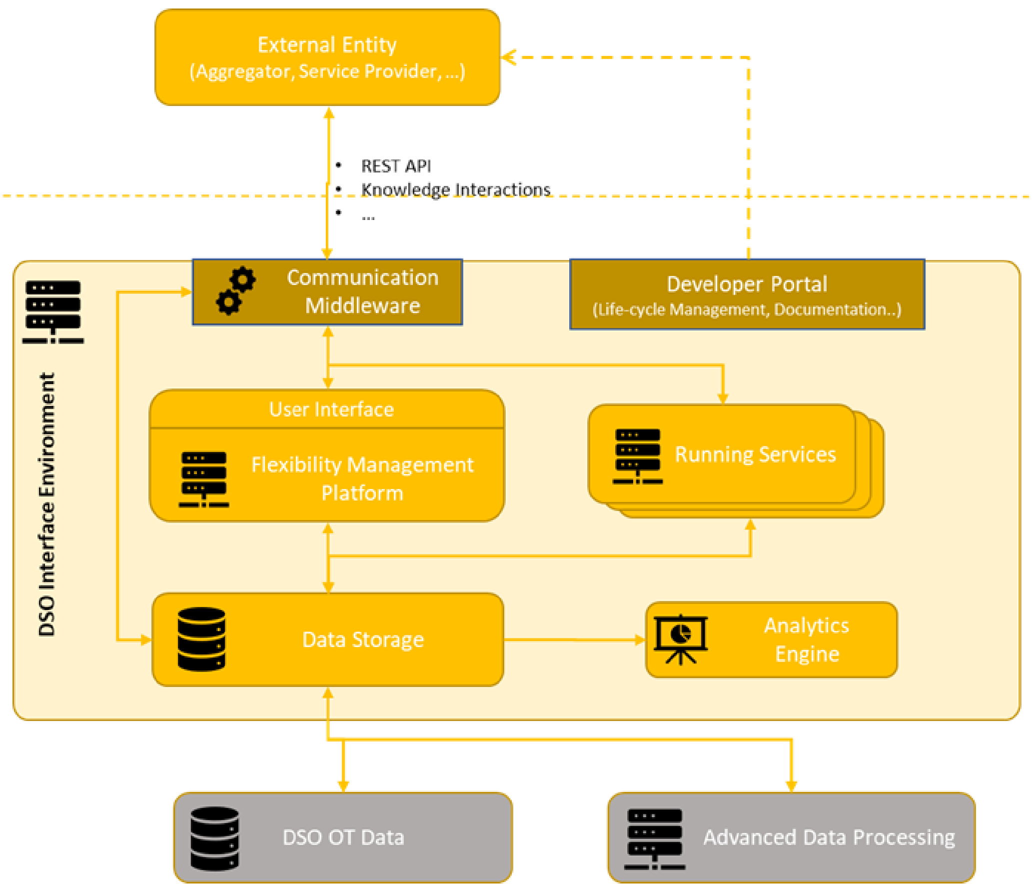

FIGURE 26 - DSO INTERFACE FUNCTIONAL ARCHITECTURE

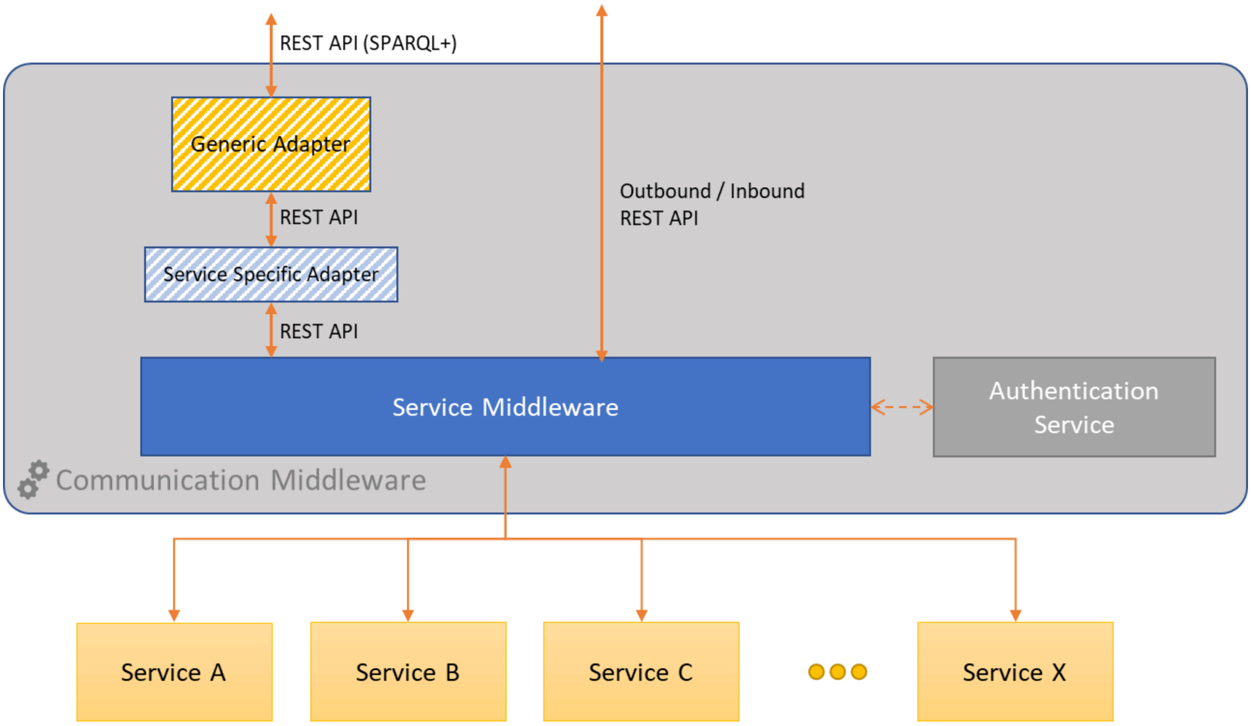

FIGURE 27 - DSO INTERFACE COMMUNICATION MIDDLEWARE

4.2.2 DSO FLEXIBILITY MANAGEMENT PLATFORM

In InterConnect, according to the project use cases identified (see section 1.2), the DSO assumes the role of Neutral Market Operator, being responsible for the main processes for flexibility procurement: forecasting, procurement or market operation, delivery and settlement (see Figure 6).

The DSO Interface will enable procurement of flexibility provided by aggregators or directly by the consumers, ensuring the required data exchange between DSO legacy systems (CRM, ADMS, AMI) and the external flexibility providers and aggregators. Focusing mainly on the procurement process (within the scope of the project), the DSO Interface incorporates the Flexibility Management platform (Figure 26) responsible for managing all the processes and data exchanged, namely:

Interact with ADMS for identifying flexibility needs for the next day or hours:

- Interaction with the Power Flow analysis tools from the DSO to retrieve the flexibility needs per node for the different timeframes
- Ensure the translation of Power Flow analysis results into Flexibility Needs according to the correspondent data structure – connection with other systems like CRM is also mandatory to verify the eligible consumers
- Request/Send (may vary according to the implementation scenario – see HLUC10 scenarios) using the DSO Interface APIs the DSO’s flexibility needs all eligible flexibility providers

Flexibility offer processing, validation and selection:

- Receive, validate and manage flexibility offers sent by flexibility providers – check their eligibility
- Sort, select and compile (using technical and financial rules) the list of desired/selected flexibilities offers

Check delivery of services and manage settlement data exchange:

- Ensure technical validation of flexibility plan trough integration with Power Flow analysis tools
- Reply to flexibility providers with the selected flexibility offers
- Manage the settlement of contracted services
- Report the fulfilment or not of flexibility needs to the DSO activate contingency or mitigation plans in more urgent situations/constrains.

The Flexibility Management platform is one of the running services inside the DSO interface, as detailed before, it will directly handle the operations related to the communication of needs, gathering of offers, and activation of flexibility. Besides the internal functions of this running service, the flexibility management platform will be dependent on another DSO interface services, namely for:

- Registry for flexibility aggregators/providers whose interaction is enabled
- Communication of flexibility metering after activation of flexibility
- Authentication purposes and security mechanisms for accessing the APIs

4.2.2.1 DSO INTERFACE – FLEXIBILITY MANAGEMENT PLATFORM IMPLEMENTATION IN PORTUGUESE PILOT

The DSO Interface will be fully implemented and tested in the Portuguese pilot, including the Flexibility Management Platform. According to HLUC10, the DSO Interface will enable the procurement of flexibility for the day-ahead and intraday management of voltage and grid congestions at the MV and LV networks. As referred before, the DSO will be responsible for managing the flexibility procurement process, interacting directly with flexibility aggregators, namely:

- CyberGrid flexibility aggregation platform, aggregating and managing flexibility from residential consumers. The platform will be adapted according to the guidelines derived in Task 4.4.
- Sensinov flexibility management platform, responsible for managing and aggregating flexibility from the supermarkets.
- Thermovault platform aggregating the flexibility provided by existing electrical water heaters.

These three platforms are going to offer bids according to published flexibility needs and be responsible for ensuring the execution of their respective activation plan.

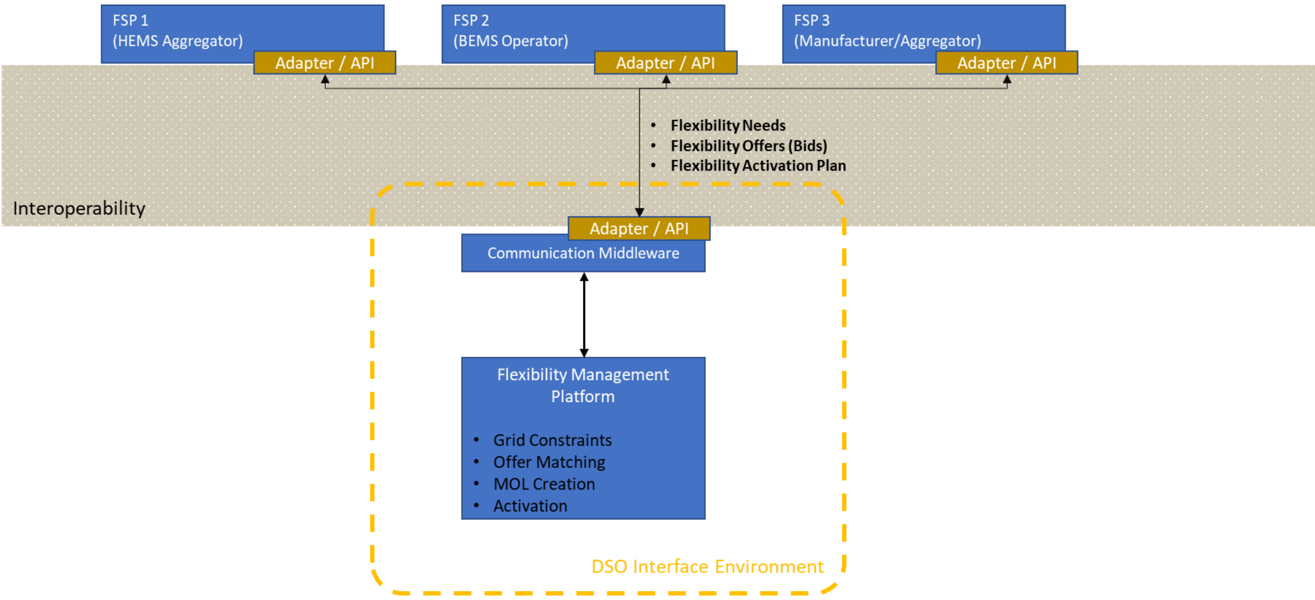

FIGURE 28 – FLEXIBLITY MANAGEMENT PLATFORM - PORTUGUESE PILOT IMPLEMENTATION

The foreseen interactions between the DSO Interface for the mobilization of flexibility are detailed in D4.2, considering REST API specification. However, as discussed in Chapter 5, flexibility procurement (see section 4.3.1) will be also modelled in SAREF, ensuring full integration with IFA. This will ultimately allow to provide a standard and interoperable way for new providers of flexibility to engage with the DSO. This implies the creation of compatible SAREF graph patterns for the specified API messages and the development of a SSA (WP3), and also the deployment of the necessary IC Generic Adapter (WP5).

4.3 DSO INTERFACE FLEXIBILITY AND RUNNING SERVICES

The DSO interface considers a set of core-service controllers handling data exchange and control business logic, described in more detail in Table 17. The table focus on the flexibility and running services, required to implement the InterConnect use cases involving the DSO and other external actors. More details on the other modules of the DSO Interface will be provided in Deliverable 4.2.

TABLE 17 - DSO INTERFACE INTEGRATED SERVICES.

Data exchange and management services platform	Scope and objectives	DSO internal systems	External systems
Authentication, access and control	Managing registration, data consent and authentication and communications monitoring	n.a.	All systems involved in DSO services
Flexibility Procurement Data exchange	Management of data exchange and chronogram involved in flexibility procurement process (e.g., registration and pre-qualification, requests and offers according to flexibility zones/perimeter, validation and settlement).	– SCADA/ADMS – Network planning and regulation departments	– Aggregator Platform – Neutral Market Flexibility Platform (if external to DSO)

Data exchange and management services platform	Scope and objectives	DSO internal systems	External systems
Dynamic network tariffs data exchange	– Manage daily updates of network tariffs. – Forward to AGG or HEMS/BEMS according to network areas	– SCADA/ADMS – Network planning and regulation departments – AMI/AMM (if DSO has the role of MDO)	– Aggregator Platform – Meter Data Management (in case of external MDO) – HEMS/BEMS
Topology and consumer connection information management	– Mapping network nodes with flexibility zona/area/node from the request and offers – Mapping consumer connection codes and flexibility zones – Mapping information from HEMS to observability data	– SCADA/ADMS – AMI/AMM (if DSO has the role of MDO) – OMS	– HEMS/BEMS – Data Analytics platform
Network observability and grid constraints data exchange	– Mapping grid constraint information for support operation of P2P energy communities trading and other energy market activities (BRP, aggregator optimal operation) – Processing of data from HEMS observability services (voltage, fault management, etc.)	– SCADA/ADMS – AMI/AMM (if DSO has the role of MDO) – OMS	– HEMS/BEMS – Data Analytics platform – Aggregator Platform – Energy Community Management platform
Open Data and Analytics data exchange service	– Anonymization and aggregation of load profiles from smart meters according to service requirements	– AMI/AMM (if DSO has the role of MDO)	– HEMS/BEMS – Data Analytics platform – Aggregator Platform

Below the each service is characterized and the data exchange between the DSO interface and the actors identified in Figure 23.

4.3.1 FLEXIBILITY PROCUREMENT

Flexibility Procurement Data Exchange includes the data related with flexibility forecast and procurement processes involved in InterConnect use cases (see Table 1) for the Portuguese and Belgium pilots. Table 18 details the data exchanged during flexibility procurement and trading, namely the flexibility forecasts, requests presented by the DSO and the offers presented by the Aggregator. These messages can be exchanged directly between the DSO and the Aggregator (as in the PT demo HLUC10) or through a neutral market platform. If implemented directly, for example through bilateral contracts, the DSO Interface will need to manage all the requests and offers presented.

The flexibility forecast can either be individual or aggregated at the energy community or aggregator level, allowing the DSO to estimate more accurately the status of the distribution network for the next day/hours, based on the expected response of the consumers to the flexibility requests.

Data exchange involved in the registration, validation and settlement were not considered in this table, since they won't be the focus of Portuguese and Belgium pilot demonstrations.

TABLE 18 - FLEXIBILITY DATA EXCHANGE WITH DSO INTERFACE.

Flexibility data exchange	From -> To	Description of relevant variables
Flexibility Forecast	BEMS-> DSO BEMS -> Aggregator -> DSO	Flexibility based on the usage planning
Flexibility Request	DSO -> (Flexibility Platform) -> Aggregator	Flexibility Zone/Area/Node where flexibility is needed
		Start
		Duration
		Power_up or Power_down
Flexibility Offers	Aggregator-> (Flexibility Platform) -> DSO	Flexibility needs for a given time frame and location
		Flexibility Offers (power up, down, duration, start, price)
		Baseline (load forecast, net load, etc.)
		Flexibility Action Plan/adjustments/additional needs
Flexibility Offers Selection	DSO -> (Flexibility Platform) -> Aggregator	Flexibility offers (with the possibility of selecting only partial amounts or for delivery times)
Flexibility Bilateral Contract	DSO -> (Flexibility Platform) -> Aggregator/Consumer	Flexibility Zone/Area/Node where flexibility is needed
		Capacity reserved (power)
		Period for activation and recovery time
		Maximum number of activations
		Reserved capacity remuneration
		Activation price
		Penalties

4.3.2 DYNAMIC NETWORK TARIFFS

Dynamic network tariffs data exchange Table 19 details the data exchanged when DSO and/or the retailer provides a dynamic tariff structure to the consumer either through the Smart Meter (in the case of the DSO providing network access dynamic tariff) or sending to the HEMS/BEMS /in the case of the retailer providing an energy dynamic tariff).

BEMS operation plan can be exchanged directly with the DSO or through an aggregator. It will allow the DSO to estimate more accurately the status of the distribution network for the next day/hours, based on the expected response to the tariffs.

This service was defined considering the use cases German, Belgium, France and Italy use cases (see Table 1).

TABLE 19 - DYNAMIC TARIFFS AND INCENTIVE TABLE DATA EXCHANGE WITH DSO INTERFACE

Data Exchange	From -> To	Description of relevant variables
Tariff structure	Energy: Retailer -> BEMS Grid: DSO -> Smart Meter	Array with prices and timings
Incentive-based table for energy consumption/production with transmission fee	DSO-> BEMS/HEMS Or DSO->Smart Meter	Array with power, energy and CO2 limits according to the dynamic tariff prices and timeline
Prosumption Plan (Optimal, adjusted and scheduled)	BEMS-> DSO BEMS -> Aggregator -> DSO	Optimal: Proposition plan optimized according to tariff structure Adjusted: Adjusted plan according to tariff structure Scheduled: User consumption/production scheduled profile
Power limitation	DSO -> BEMS/HEMS	Limits on contracted and real-time power consumption (single or time-series) Limits on power injection (single and time-series)

4.3.3 TOPOLOGY AND CONSUMER CONNECTION INFORMATION

Network topology and consumer connection information are critical information for an effective procurement of flexibility and for improving network observability. However, DSO is not willing to provide detailed information of network topology to external actors and market platforms.
As discussed in section 2.3.2, one of the steps in flexibility procurement is typically the identification of congestions zones to define topological grid regions where resources can be aggregated due to their similar impact on the grid.

The congestion zone can consist of a pre-defined network area or aggregation node represented by a group of eligible consumers identified by their Smart Meter identification code, as described in Table 20. Aggregation nodes can also be represented by a MV or LV feeder or distribution substation code that connects a group of consumers through the smart meter identification code.

The matching between the aggregation nodes and the network nodes will be ensured internally by the DSO, based in this service to match this information with network planning and operation tools.

TABLE 20 - TOPOLOGY AND CONSUMER CONNECTION INFORMATION.

Data exchange	From -> To	Description of relevant variables
Smart Meter identification code	MDO/DSO	Unique code associated to a smart meter and the data collected.
MV and LV feeder identification code	DSO	Unique code associated to a MV or LV feeder where several LV and MV consumers are connected (including flexibility providers)
HV/MV or MV/LV substation code	DSO	Unique code associated to HV/MV or MV/LV substation
Flexibility Node	DSO	Unique code associated to a HV/MV, MV/LV substation or a specific node of the network.

Flexibility Zone/Area where flexibility is needed	DSO	Code associate to a flexibility aggregation node that could correspond, LV or MV feeder or an entire MV network or region.

4.3.4 NETWORK OBSERVABILITY AND GRID CONSTRAINTS

One of the innovative services enabled by the DSO Interface consists in the network observability services proposed in the Portuguese demo (see HLUC 11 in Table 1) and that are being developed under Task 4.3. The main objective is to valorise consumers data collected from the HEMS, to improve distribution network observability. Three main services are foreseen:

- Using HEMS data to improve distribution network fault location (PUC 11-1). HEMS connectivity data is processed by a data service provider to identify potential service interruptions in a given geographic area and then notify the DSO.
- Quantification of consumers load elasticity (PUC 11-2), that based in the historical consumption data collected from smart meters or HEMS assess the result of flexibility mechanisms, namely dynamic tariffs and market-based services. The service can be relevant to both DSO and aggregators.
- Assessing LV network operation status (PUC 11-3), that assesses the impact of net load or specific load types (e.g. EV, heat pumps, PV) in the voltage profile of LV networks. This service is relevant to the DSO, reducing LV grid monitoring requirements and enabling the identification of network restrictions and characterization of relevant loads.

The data required to implement these services is described in Table 21.

TABLE 21 - NETWORK OBSERVABILITY AND GRID CONSTRAINTS.

Data exchange	From -> To	Description of relevant variables
Active Energy Consumption	Smart Meter-> (MDO ->) DSO	Net active energy (consumed and injected) - daily aggregated and daily load profiles (kWh)
Reactive Energy Consumption	Smart Meter-> (MDO ->) DSO	Net reactive energy (QI, QII, QIII, QIV) - daily aggregated and daily load profiles kVar.h)
LV node voltage monitoring	Smart Meter-> (MDO ->) DSO BEMS/HEMS -> (Data Service Provider) -> DSO	Average voltage profile (V) or measurement
MV/LV voltage monitoring	Grid meter -> DSO	Phase voltage measurement or profile collected at the LV bus of the MV/LV substation
Watchdog/Heartbeat	BEMS/HEMS -> (Data Service Provider) -> DSO	Specific HEMS disconnection
		HEMS disconnected in a given geographic region (street, city, etc.)
Sub-metering	BEMS/HEMS -> (Data Service Provider) -> DSO	Load diagram of specific loads (heat pump, EV, PV,…)

4.3.5 OPEN DATA AND ANALYTICS

The open data analytics services are provided by the DSO to consumers and market players. The main goal is to valorize smart meter data for energy consumption awareness as well as flexibility market activities. The service mainly consists of procedures for the anonymization and aggregation of load profiles from smart meters according to service requirements. Table 22 identifies the relevant data for the implementation of this service.

TABLE 22 - OPEN DATA AND ANALYTICS.

Data exchange	From -> To	Description of relevant variables
Active Energy Consumption	Smart Meter-> (MDO ->) DSO	Net active energy (consumed and injected) - daily aggregated and daily load profiles (kWh)
Reactive Energy Consumption	Smart Meter-> (MDO ->) DSO	Net reactive energy (QI, QII, QIII, QIV) - daily aggregated and daily load profiles kVar.h)
Contracted power	Smart Meter-> (MDO ->) DSO	Contracted power (kVA)
	DSO (-> MDO) -> Smart Meter	Recommended contracted power (kVA)
Anonymized meter data and Load profile	DSO-> Data Service Provider/Aggregator/Retailer	Anonymized load profile per grid connection point of geographic region (P, Q) and readings
Meter Data and Load profile	DSO-> Data Service Provider/Aggregator/Retailer	Load profile per grid connection point (P, Q) and other readings
Grid monitoring (outages, patterns and behaviours)	BEMS/HEMS -> (Data Service Provider) -> DSO	Voltage and frequency measurement (single value or time-series)

5. ANALYSIS OF APPLICABLE INFORMATION MODELS

Based on the description of the DSO Interface in the previous chapter, this chapter identifies and then analyzes applicable information model, standards and frameworks that can help ensure a standardized and interoperable interaction between the DSO and the other relevant stakeholders using the DSO interface.

In section 5.1 information models are identified that could be applied for the implementation of the DSO interface. In section 5.2, a gap analysis is performed in order to understand the applicability range of each information model (standard) and identify its gaps regarding the data exchange identified (see previous 4.1). Section 5.3 concludes with recommendation to bridge the gaps.

5.1 IDENTIFICATION OF APPLICABLE ONTOLOGIES, DATA MODELS AND INTERFACES

This InterConnect deliverable defines the semantical concept of an information model to describe data semantics for a certain domain. It describes concepts and their relationships in such a way that information about (related) concepts in that domain can be exchanged between parties, with preservation of meaning, as both parties have the same information model of the domain, they are exchanging information about.

Information models can be used by software engineers for the creation of interfaces between information processing systems. The less ambiguous an information model is described, the smaller the chance of miscommunication between parties.

This section provides an overview of information models that have been identified by the InterConnect as potentially applicable for the implementation of the DSO Interface. Note that information models are often part of the definition/specification of a protocol to exchange information. As a result, information models are often referred to by the name of the corresponding protocol. The difference in this deliverable between an information model and a protocol is that a protocol also describes why and in which order information is and/or needs to be exchanged.

5.1.1 USEF FLEXIBILITY TRADING PROTOCOL (UFTP)

UFTP is a subset of the USEF (see Chapter 2) focused on the exchange of flexibility between Flexibility Service Providers / Aggregators and DSOs and describes the information model of market interactions. It can also be used as a stand-alone protocol for flexibility forecasting, offering, ordering and settlement processes. Figure 29 lists the core UFTP components in process and market messages [55].

UFTP is a subset of the USEF Framework, focused on the exchange of flexibility between Aggregators and DSOs, and describes the market interactions. It can be used as a stand-alone protocol for flexibility forecasting, offering, ordering and settlement processes. Figure 29 lists the core UFTP components in process and market messages.

Core UFTP components	USEF 2015	UFTP	Signaled in CRO?
UFTP Process:			
Day-ahead Flex trading	o	o	-
Redispatch responsibility choice	-	o	Y
Baseline choice	-	o	Y
Market messages:			
FlexRequest	o	o	-
FlexOffer	o	o	-
FlexOfferRevocation	o	o	-
FlexOrder	o	o	-
FlexSettlement	o	o	-

FIGURE 29 - CORE UFTP COMPONENTS IN PROCESS AND MARKET MESSAGES [55].

Several projects that have used the USEF have experimented UFTP and derivatives of it. A few examples will be shortly discussed here.

USEF as used in H2020 project InterFlex

In the H2020 project InterFlex, Dutch partners have applied USEF in Netherlands demonstration pilot, more specifically USEF+ was used to connect the DSO Grid Management System to three different Commercial Aggregators that offer flexibility to this DSO via their Flexibility Aggregation Platforms, considering the architecture represented in Figure 30 [56].

One of the drawbacks identified during the demonstration is that all messages in the USEF specification that can be used for congestion management, are congestion point based. Congestion point is a hierarchical point in the network, where congestion can occur downstream. Often this is a single asset (transformer, cable). This means that all flexibility trading messages only consider one congestion point while there can be a relation between two or more congestion points. As a result, it might be that solving congestion for congestion point A will lead to (more) congestion on congestion point B.

In their InterFlex deliverable D7.7. [57], several conclusions and recommendations are provided. Interesting in the context of this InterConnect deliverable are the following recommendations:

- Technical system recommendation: do not design a too complex system to start with. Start with a less complex system based on the e.g. the Dutch InterFlex architecture. The current system is universal and scalable, but when the specific application area is known, a simplified version of the system can be used.
- Separate the USEF communication protocol and the USEF market model so the communication protocol can be applied for several market models (e.g. bilateral contracts, open flexibility market, variable tariffs, etc.).
- Regulation recommendations: It is recommended to study which new or adapted regulation enables simpler business models. Also, to ensure a good and reliable pricing or business model, since a local flexibility market can suffer from a lack of competition.
- It is also recommended to study which tariff, and taxation system is best applicable and incentivizes the use of local flexibility. In this context also a DSO 'bandwidth model' (dynamic tariffs) can be considered.

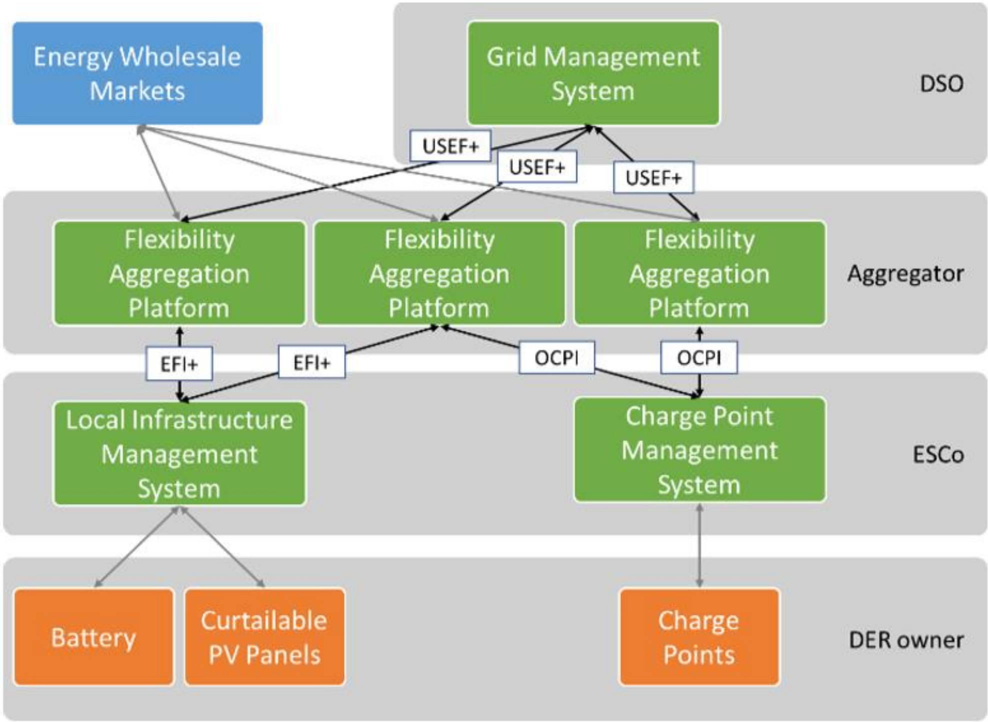

FIGURE 30 - INTERFLEX ECOSYSTEM ARCHITECTURE.

Another USEF related project

DCM with Flex Trading was developed in the H2020 FHP project as an extension/enrichment to USEF, based on experiences using USEF in an earlier H2020 REnnovates project. See section 5.2 for more details on the data exchange and relation with USEF.

5.1.2 FLEXOFFER

FlexOffer is an application-level communication protocol dedicated to flexibility trading between prosumers, aggregators and DSOs to define and transmit flexibility offers (e.g. an offer from a prosumer to an aggregator).

An overview of the FlexOffer concept can be found in [58]. It unifies flexibility representation, is adaptable, and details the messages used but not the use cases. FlexOffer allows the aggregation of flexibility offers between different types of prosumers and different aggregators. FlexOffer has been used in several innovation projects (Mirabel, Totalflex, Arrowhead, DiCyps, Goflex, GIFT, and Fever) since 2010.

5.1.3 CIM & CIM-MARKET

The **Common Information Model (CIM)** [59] is defined in the International Electrotechnical Commission (IEC - Technical Committee 57) 61970/61968/62325 standard series that promotes interoperability in electric power systems:

- IEC 61970 Energy management system application program interface:

    - IEC 61970 is the series of standards that provide a solution by defining a common information model to describe the electrotechnical relationships between different systems and components of power grid management.
    - It standardizes a set of interfaces that provide access to all applications and systems.
    - It defines an application program interface (API) for the integration of internal EMS applications from different manufacturers.
- IEC 61968 Application integration at electric utilities - System interfaces for distribution management:
    - The IEC 61968 standard is an extension of the information model defined in the IEC 61970 standard to cover aspects of management and operation of the distribution of electrical networks (e.g. monitoring of operations, work planning, customer invoicing, etc.).
- IEC 62325 Framework for Energy market communications
    - A series of standards that describes a framework for communications relating to the deregulated energy market.
    - The main objective of IEC 62325 is to facilitate the integration of application software for the market, developed independently by different vendors. Message exchanges are defined to allow these applications or systems to access public data and exchange information regardless of how that information is represented internally.

CIM is a domain model (e.g., UML class model) based on electronic exchange standards to describe concepts such as topology, asset descriptions and component descriptions. CIM is an abstract model that represents all the major objects in power systems and market operations. It facilitates interoperability in power systems namely in outage management, customer information management and exchanges between utilities/DSO. CIM is used at least since 2007 by TSOs and are being implemented for the Balancing Code, Operational Planning & Scheduling to guarantee the "*interoperability*" between the actor's participating to these processes.

CIM standardizes interoperability in energy management functionalities, such as network operations, and electricity markets, power system distribution, and information exchange between them [59]. Several extensions have been proposed to adopt the CIM for further applications, such as the operation of electrified railway systems. Hundreds of classes organized in packages are included in the CIM data model. Among all the CIM packages, Core, Wires, and Topology packages contain classes to represent electricity networks (e.g., cim:Substation, cim:Breaker, and cim:Disconnector) and electrical connections (e.g., cim:Terminal, cim:ConnectivityNode).

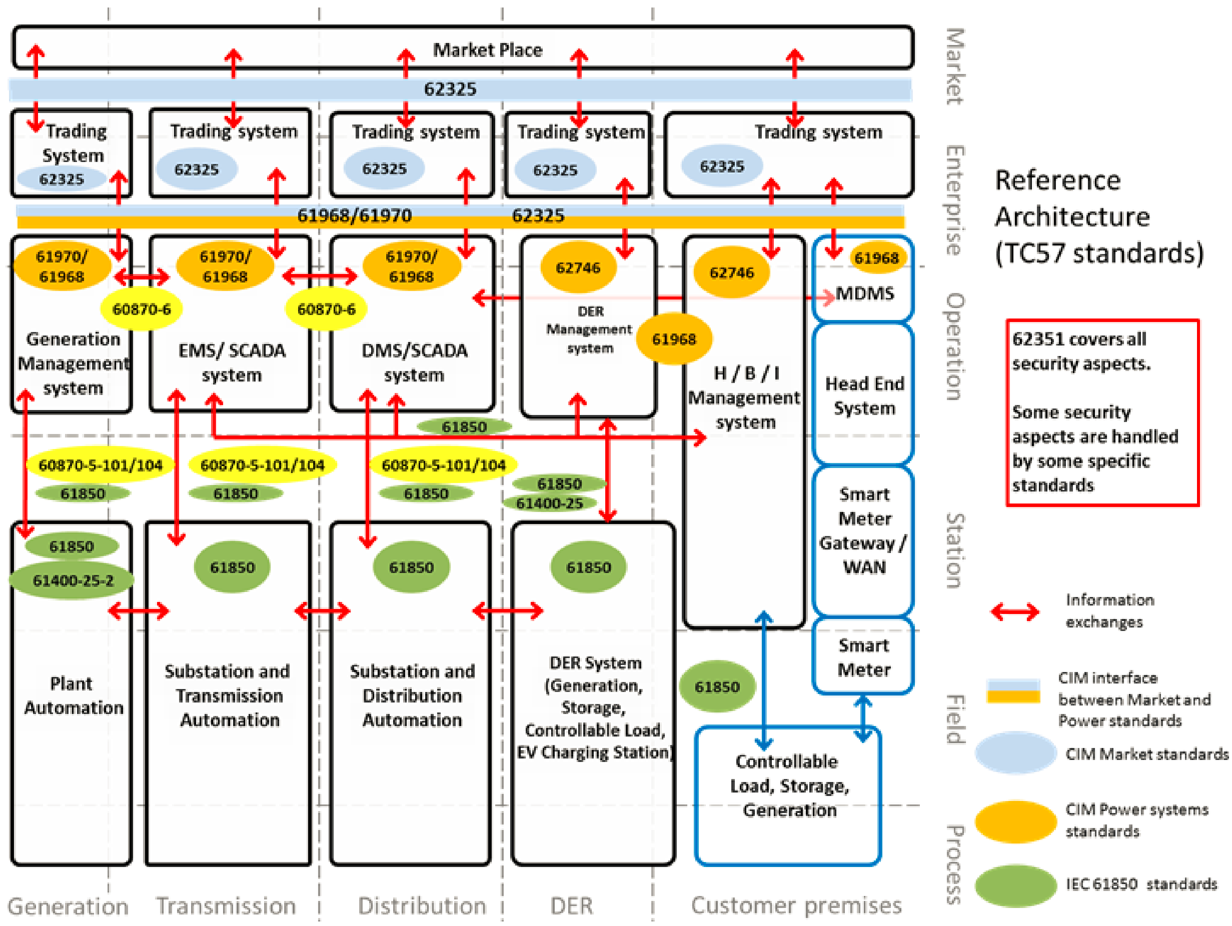

FIGURE 31 – TC57 REFERENCE ARCHITECTURE: CIM AND OTHER IEC STANDARDS

The European Network of Transmission System Operators for Electricity (ENTSO) provides tests to check the syntax of the latest ENTSO-E XML schema to ease the translation between ENTSO-E XML instances and IEC CIM XML instances (using XSLT transformation). The IEC TC 57 series IEC 62325 covers the needs for market exchanges, scheduling for balancing and transparency, and IEC 62325-301 184 describes the CIM-Market.

CIM is used as an enabler by more than 100 companies in the world (about 42 TSOs from 34 countries). The main advantages of CIM are:

- Time saving when creating a new interface (the information to be exchanged being defined elsewhere in the shared exchange model)
- Reduction of total data administration and IT development costs by limiting the number of specific interfaces to be developed
- Better control and readability of the information exchanged
- Increased guarantee of the overall consistency of data
- Easier learning and reduction in training time

The CIM is currently maintained in UML, but standardized documentation with UML diagrams is not freely available. The implementation of CIM is dependent on the interpretation of the standard, consisting in one of the main barriers for the integration of new applications and systems. In order to overcome this barrier CIM has been adopted by emerging ontologies as discussed in section 5.1.5 [59].

5.1.4 EEBUS (SPINE/SHIP)

The EEBUS Initiative e.V. is a non-profit association with leading global manufacturers from the sectors of network building technology, electromobility and energy. The cross-industry network plays a central role and through this exchange a common understanding is developed, creating the basis for new use cases and business models creating market-driven solutions. The EEBUS organizes business workshops as well as technical work meetings. EEBUS contributes with the experience and results from the joint development of standards to the important standardization bodies and plays a key role in shaping future standards.

EEBUS SPINE and EEBUS use cases are standardized in the following:

- CENELEC EN 50631 (Interoperable Connected Household Appliances)
- EU Framework SAREF (Smart Appliances Reference Framework) ETSI TS 103 264/SAREF4ENER
- German VDE-AR-E 2829-6-x (Technical information exchange at the interface to the property and the elements of the customer's facilities located there) (to be published soon)
- German VDE-AR-E 2122-1000 (Standard interface for charging points/charging stations for connection to local power and energy management) (to be published soon)

Further domains for standardization are being consistently promoted.

In addition to providing solutions for energy management inside the premises, such as EV Charging, monitoring and comfort, and increase of self-consumption, EEBUS provides capacity management, allowing DSOs to limit the premises' power consumption as a curative measure in case of grid congestion in close collaboration with German FNN and BSI. New developments include solution for flexible tariffs as a preventative measure to avoid overload and underload situations in the first place.

5.1.5 ONTOLOGY CATALOG FOR ENERGY

Ontology-based IoT energy projects were analysed within the LOV4IoT-Energy ontology catalogue. The catalogue collected a total of more than 37 projects (in February 2021) published from 2009 to 2020 related to smart energy and the grid. The knowledge aggregation has been collected since 2012 and referenced within the LOV4IoT-Energy ontology catalogue (see Figure below). It deals with more and more expertise and synonyms (e.g., smart grid, renewable energy, power plant, micro-grid, CIM, Flexibility, DSO, etc.). It also provides tools to support the reuse of the analysis outcome (e.g., a dump of ontology code, web services, and web-based ontology catalogue).

As an example, SAREF4ENER, which is used within Interconnect, is referenced in the ontology catalog. **SAREF4ENER** (previously called SAREF4EE) is the SAREF extension for EEBUS and Energy@Home in the energy domain. Energy@Home develops and promotes technologies and services for energy efficiency in smart homes, based upon the interaction between user devices and the energy infrastructure. EEBUS is an important initiative in the area of energy management, which has its roots in the sector of smart and renewable energy (see also below). EEBUS developed a standardized and consensus-oriented smart grid and home energy management and networking concept. SAREF4ENER is developed upon data models from Energy@Home (initially UML class diagram) and EEBUS (initially XSD specification). SAREF4ENER provides interoperability among various proprietary solutions developed by the smart home community. SAREF4ENER, smart appliances from manufacturers that support the EEBUS, or E@H data models will easily communicate with each other using any energy management system at home or in the cloud by using SAREF4ENER. In the ETSI specification, the SAREF4ENER is illustrated with 2 use cases: 1) exchange configuration information of devices in order to connect to each other, and 2) monitor and control the start and status of the appliances. The ontology is currently being extended with additional use cases used in Interconnect pilots, including use cases for grid interaction, with active participation from **EEBUS**.

LOV4IoT-Energy
Ontology Catalog - Reusing Domain Knowledge Expertise

Before to reinvent the wheel, maybe you can reuse the following existing ontologies referenced in this ontology catalog with minor modifications. Sometimes these domain ontologies, although very interesting, are not referenced yet on the Linked Open Vocabularies (LOV) since they need to follow more Semantic Web best practices.

smart energy The **LOV4IoT-Energy** ontology catalog references **37** ontology-based research projects for Energy smart energy

Please remember to cite our work: scientific publications here.

Ontologies have been colored as follows:

The ontology will never be available (lost, confidential, etc.) :-(	We are waiting the response from the authors if they can publish the ontology online	Authors are publishing online the ontology (ongoing work)	Ontology published online but the Semantic Web best practices can be improved to be on LOV.	Ontology published online and referenced by LOV since Semantic Web best practices are adopted! :-)))	Already on LOV - No email sent
Nb onto: **2**	Nb onto: **15**	Nb onto: **8**	Nb onto: **6**	Nb onto: **4**	Nb onto: **2**

FIGURE 32 - ONTOLOGY CATALOG FOR ENERGY [64]

A second example is an **energy ontology-based on the CIM model**. In [62] a converter between Semantic Web Rule Language (SWRL) and Jena Rule Language (JRL) rules was design to ease the translation between standard data models in the Smart Grids such as the IEC 61970/61968/62325 Common Information Model (CIM) and IEC 61850 Configuration Language (SCL) data models. They can solve the following mismatches: 1) Resolving Naming Mismatches, 2) Resolving Multilateral Correspondences, and 3) Resolving Covering Mismatches. In an ontology matching system for future energy Smart Grids finds complex correspondences by processing expert knowledge from external domain ontologies. The tests carried out are based on the main interoperability issue within Smart Grids: interactions between CIM and SCL data models. In such tests, the proposed system outperformed one of the best ontology matchers according to the Ontology Alignment Evaluation Initiative (OAEI). They use the electrical and electronic terminology database called electropedia.

OpenADR ontology [63] achieves semantic interoperability among various Demand Response (DR) stakeholders. The ontology development methodology Linked Open Terms (LOT) is used to design the OpenADR ontology that also encourages the reuse of ontologies. OpenADR reuses OWL-Time for temporal and GeoSPARQL for geospatial. OpenADR covers concepts such as location, equipment, measurements, events, and Demand-Response.

The SARGON ontology is made to enable network technologies such as 5G to process and retrieve massive data and address heterogeneity challenges [52]. SARGON is made of various interconnected ontologies dedicated to smart grids and buildings. These can be described in four groups; the first one concerns ontologies which describe the nature of a person, company, building and address spaces and geometrical data (ie. area place, floors). The second concern devices and builds on SAREF but extending it according to the energy equipment including industrial equipment, energy generators, and system resources. The third concern services in the smart grid and building sphere, such as controlling monitoring and protection. Lastly it covers the relations in the electrical networks based on CIM and IEC 61850 [53]. The benefit of applying the SARGON is that it can incorporate data beyond classical electricity data, as it incorporates data from other sources standards.

FIGURE 33 - SARGON ONTOLOGY MAP.

5.2 GAP ANALYSIS

The previous section provided a selection of information models that had been identified by the InterConnect project as potentially applicable for the implementation of the DSO interface. In this section a gap analysis is performed regarding the data exchange identified (see previous section 4.3). This gap analysis enables the InterConnect project to understand the applicability range of each of these information models.

5.2.1 HIGH LEVEL INFORMATION MODEL ANALYSIS

Before determining where the gaps are between the current information models and the needs of the DSO Interface from Interconnect, a recapitulation of the information models in the previous section is provided in Table 23. The relevancy of the information model (standard) with respect to the DSO Interface is described at a high abstraction level in terms of identified benefits and potential limitations. Also, for each information model, it is described which InterConnect partner has used it already.

TABLE 23 - COMPARISON OF CIM-MARKET, FLEXOFFER, USEF/UFTP AND EEBUS.

Information model	Relevancy to DSO interface	Used by Interconnect partners
Common Information Model (CIM) European style market profile	Identified benefits: • Supported by ENTSO-E • Covers all needs for flexibility trading and flexibility provision (including mFRR activation) • All relevant information available form Entso-E's EDI library • Used by several TSOs already for modeling their information Potential limitations: • Represents primarily the perspective of the TSOs and needs (minor) extensions for DSO's purposes • Is so large that it requires a relative large amount of time and effort to understand and even the TSOs have issues in interpretation (national implementation may slightly deviate from the standard) • Not intended for application on field level ("last mile")	cyberGRID implemented parts of it commercially (ancillary service trading and provision) in 2 European countries & tested it for DSO flexibility provision in Integrid (with INESCTEC). Used by Enedis for its flexibility platform (exchanges between regional network management agencies and flexibility service providers as it is described in the 3.2. E-FLEX PLATFORM) and for some data exchanges between information systems (e.g., load curves exchanges between Enedis and communities) (CIM-market (IEC 62325)).
FlexOffer	Identified benefits: • Flexibility addressed • Flex Market • Used in innovation projects (Mirabel, Totalflex, Arrowhead, DiCyps, Goflex, GIFT and Fever) Potential limitations: • Does not cover the physical concept of an electrical grid	-
USEF Flex Trading Protocol (UFTP)	Identified benefits: • Flexibility addressed • Flex Market • Completeness • Ready to be used by DSO • Used in projects and pilots • Public standards available Potential limitations: • Does not cover the physical concept of an electrical grid	TNO (in the Interflex project, together with a Dutch DSO).
EEBUS SPINE and SHIP protocols	Identified benefits: • Flexibility addressed • Direct usage of DSO • Same protocol for grid interaction and on-premises • Industry-based and market-driven • Public standards available Potential limitations: • Highly focussed on connecting electrical devices to the grid, at a relatively high abstraction layer.	EEBUS partners, e.g. DAIKIN, KEO, FRAUNHOFER, BOSCH, MIELE, VAILLANT and WIRELANE.

5.2.2 COMPARATIVE ANALYSIS OF INFORMATION MODELS FOR DATA MANAGEMENT SERVICES DATA EXCHANGE

With the recapitulation of DSO interface relevant information models in mind, these selected information models can now be compared to the required data exchanges of each Data Management Services of the DSO interface.

5.2.2.1 FLEXIBILITY PROCUREMENT DATA EXCHANGE

For this interface, that covers exchange of (1) flexibility forecast from the BEMS or Aggregator, and (2) flexibility procurement data with the Aggregator or Flexibility Platform, the relevant information models are: USEF/UFTP, FlexOffer, CIM/CIM-Market, and SAREF.

Table 24 summarizes the required data exchanges, based on the DSO Interface service characterization in section 4.2.2, and the coverage of this data by each of the selected information models.

TABLE 24 – APPLICABILITY OF INFORMATION MODELS FOR FLEXIBILITY PROCUREMENT SERVICES.

Data	SAREF	Flex Offer	USEF/ UFTP	CIM & CIM-Market
Flexibility Forecast	No	No	Yes	Yes
Flexibility Request	No	No	Yes	Yes
Flexibility Offers	No[1]	Yes	Yes	Yes
Flexibility Offers Selection	No	No	Yes	Yes
Flexibility Bilateral Contract	No	No	Yes	Yes

[1] "saref:offers" is a property that defines a relationship between a device and a service, not a flexibility offer.

5.2.2.2 DYNAMIC NETWORK TARIFFS DATA EXCHANGE

For this interface, that covers exchange of (1) dynamic tariffs and fees to the BEMS or Smart Meter, (2) prosumption plan from the BEMS or Aggregator, and (3) Power limitation to the BEMS, the relevant information models are: USEF/UFTP, FlexOffer, CIM/CIM-Market, SAREF, OpenADR, EEBus, and DLMS/COSEM.

Table 25 summarizes the required data exchanges, based on section 4.2.2, and the coverage of this data by each of the selected information models:

TABLE 25 – APPLICABILITY OF INFORMATION MODELS FOR DYNAMIC TARRIFS.

Data	SAREF	Flex Offer	USEF/ UFTP	CIM & CIM-Market	OpenADR	EEBus	DLMS/COSEM
Tariff structure	Yes	Yes	Yes	Yes IEC61968	Yes	Yes (in work)	Yes
Incentive-based table for energy	Yes (Energy)	Yes	Yes	Yes	1)	Yes	Yes

Data	SAREF	Flex Offer	USEF/ UFTP	CIM & CIM-Market	OpenADR	EEBus	DLMS/COSEM
consumption/production with transmission fee							
Prosumption plan (optimal, adjusted and scheduled)	Yes (Schedule)	Yes	Yes	Yes	No	Yes	1)
Power limitation	Yes (Power)	No	No	Yes	Yes	Yes	Yes
1) No conclusive information found.							

5.2.2.3TOPOLOGY AND CONSUMER CONNECTION INFORMATION MANAGEMENT

For this interface, that covers exchange of identification data, the relevant information models are: SAREF, CIM, and IEC 61850

Table 26 summarizes the required data exchanges, based on section 4.2.2, and the coverage of this data by each of the selected information models.

TABLE 26– APPLICABILITY OF INFORMATION MODELS FOR TOPOLOGY AND CONSUMER CONNECTION INFORMATION.

Data	SAREF	CIM	IEC 61850
Smart meter identification code	Yes (saref:Meter)	Yes	Yes
MV and LV feeder identification code	No	Yes	Yes
HV/MV or MVLV substation code	No	Yes	Yes
Flexibility Node	No	Yes	Yes
Flexibility Zone/Area where flexibility is needed	No	Yes	Yes

5.2.2.4 NETWORK OBSERVABILITY AND GRID CONSTRAINTS DATA EXCHANGE

For this interface, that covers exchange of (1) energy and voltage data from the Smart Meter or MDO, (2) voltage data from the Grid meter, and (3) shortage and submetering data from the HEMS/BEMS, the relevant information models are: SAREF, IEC CIM, OpenADR, EEBus, DLMS/COSEM, IEC 61850.

Table 27 below summarizes the required data exchanges, based on section 4.2.2, and the coverage of this data by each of the selected information models.

TABLE 27 – APPLICABILITY OF INFORMATION MODELS FOR FLEXIBILITY PROCUREMENT SERVICES.

Data	SAREF	IEC CIM	OpenADR	EEBus	DLMS/COSEM	IEC 61850
	Yes (Energy)	Yes	Yes	Yes	Yes	Yes
	Yes (Energy)	Yes	Yes	Yes	Yes	Yes
	Yes (Voltage)	Yes (2)	Yes	Yes	Yes	Yes
	Yes (Voltage)	Yes (2)	Yes	Yes	Yes	Yes
	No	Yes (2)	1)	1)	Yes	Yes
	No	Yes	Yes	Yes	Yes	Yes
1) No conclusive information found. 2) Based on IEC60870						

5.2.2.5 OPEN DATA AND ANALYTICS DATA EXCHANGE SERVICE

For this interface, that covers exchange of (1) metering and contract data from the Smart Meter or MDO, (2) grid status data from the BEMS/HEMS and (3) meter data and load profile to the Data Service Provider/Aggregator/Retailer, the relevant information models are: SAREF, CIM/CIM-Market, OpenADR, EEBus, and DLMS/COSEM.

Table 28 below summarizes the required data exchanges, based on section 4.2.2, and the coverage of this data by each of the selected information models.

TABLE 28 – APLICABILITY OF INFORMATION MODELS FOR OPEN DATA AND ANALYTICS SERVICES

Data	SAREF	IEC CIM	OpenADR	EEBus	DLMS/COSEM
Active energy consumption	Yes (Energy)	Yes	Yes	Yes	Yes
Reactive energy consumption	Yes (Energy)	Yes	Yes	Yes	Yes
Contracted power	Yes (Power)	Yes	Not found	No	Yes
Anonymized meter data and load profile	No	Yes	1)	No	Yes
Meter data and load profile	Yes (Meter, Load)	Yes	Yes	Yes	Yes
Grid monitoring (outages, patterns and behaviours)	No	Yes	1)	Yes	1)
1) No conclusive information found.					

5.3 BRIDGING THE INFORMATION MODEL GAPS

The gap analysis in the previous section showed that it is not possible to use one single information model to describe the semantical concepts of all the Data Management Services of the DSO Interface. In this section a way of bridging these gaps is prescribed. First it is described how differences between demands to the DSO demands impede the creation of bridges. Then finally a method of dealing with the impediments is provided. This is also input for Task 2.4 that focusses on the Semantic Interoperability Framework and will provide output in the deliverable D2.3 Interoperable and secure standards and ontologies.

5.3.1 DIFFERENCES BETWEEN DSO INTERFACE DEMANDS

The previous sections have shown that different information models have been developed for different reasons. Different organizations have different tasks to accomplish in the domain of electricity. They share concepts at a high level of abstraction, but they do not at lower levels of more (technical) detail. For this reason, certain information models exclude certain semantical concepts because they are not relevant. This is also why certain information models describe certain semantical concepts with a lot of detail. There are information models that dedicate higher focus to electricity markets, and there are information models that have higher focus on describing the physical and logical lay-out of an electrical system. Depending on the need to accomplish a task together, different semantic concepts are exchanged between parties.

The differences between parties in the tasks to accomplish or the goals to achieve, cause them to want to have a certain information model. Parties in general are not willing to use an information model that provides information in a way that makes it more difficult for them to accomplish a task. Too much information requires extra processing. Too little information impedes carrying out a task. Also providing the same level of information in a different information model will require (potentially costly) adaptation of information processing systems.

The domain of electricity grids has been in existence for more than a century, standards for information processing in this domain have also emerged and evolved. The IEC Common Information Model (CIM) is an example. It has been evolving for many years. It has matured and been accepted by several TSOs and DSOs, even though it is such a large standard that it takes a relatively large number of resources to master it. These parties will probably not be eager to let go of an information model that have suited their needs until now. If only because of having to adapt their information processing systems that require a high level of reliability. However, even though CIM covers a lot of concepts and has matured, it is not available in terms of public software stacks that can send standardized messages which are understood in the same way by all different software stacks. The specific implementation depends on the interpretation of the party that implemented it. So, it does not suffice for the InterConnect project to do a ‘copy and paste’ of a part of the CIM. InterConnect needs to be more specific to enable interoperability and this should be done with the support of technology for creating ontologies, from information models and determining relationships between ontologies to link them. This would allow InterConnect to combine CIM with elements of the other mentioned information models that cover (e.g. flexibility) concepts in a way that is easier and/or efficient to use by certain stakeholders (at their level of abstraction).

5.3.2 BRIDGE GAPS BY SEPARATION OF CONCERNS AND LINKING

The InterConnect method of dealing with the tensions is based on two principles. First, separation of concerns, enables the application of the divide-and-conquer paradigm in solving a problem. Secondly, by not reinventing the (semantical concept of a) wheel, the number of changes and interface design and implementation work can be kept as small as possible.

Separation of concerns is done using the DSO Interface High Level Architecture (see FIGURE 25). Instead of trying to create an information model for the entire DSO Interface, each 'sub interface' is considered on its own. This removes some tensions as described above already. For example, when there is no need to exchange low level technical information ('metal used in cable') about the connection of Smart Building to the Smart Grid, only high-level abstract information (e.g. 'location in topology') is exchanged.

Not reinventing the wheel is done by combining semantical concepts from existing information models - that have been adapted by a significant number of parties in the electricty domain - on a need to have basis for supporting the demands of the different pilots involved. The combination of all the different pilots should result in a generic set of information models for the different sub interfaces in the DSO Interface architecture. For example, instead of trying to redo the work that was done for creating the CIM, InterConnect can reference to semantical concepts in an (semantical web) partially ontologized version of the CIM. This way of distilling and combining concepts from ontologies (based on existing information models) is also known as the Model Harmonisation Method (MHM) and was used in the TKI Linked Energy Data (TKI LinkED) project carried out by TNO and two Dutch DSOs (Enexis and Alliander) [66].

The actual creation of ontologies (using semantic web technology) for sub interfaces of the DSO Interface needs to be carried out in Interconnect Task 2.4 "*Semantic Interoperability Framework*" and its outcomes would be in the deliverable D2.3 "*Interoperable and secure standards and ontologies*". Where necessary, Task 5.5 "*Continuous support of the interoperable marketplace toolbox*" can use those ontologies in the deliverable D5.5 "*Interoperable marketplace toolbox v2.0*".

When designing the technical implementation of the DSO Interface as needed by the different pilots, key concepts (e.g., sensor, power, energy consumption, watt, flexibility, tariff) as introduced in Chapter 4 need to be refined and categorized in terms of the different sub interfaces. This refinement can then be sent to T2.4. There, the interlinking of key concepts in an 'per sub interface' ontology can be done using ontology matching tools. This also enables later unification of concepts and enhance semantic interoperability. A similar way to what has been done to interlinking and unifying IoT ontologies is detailed in [67]-[71]). Ontology matchings tools applied to information models that have been converted to semantic web ontologies, can help to automate the task to map concepts and determine to what extent concepts have already been covered or not.

By keeping the information models small and in line with existing information model standards, InterConnect makes it easier to let other parties adopt a particular service of the DSO Interface. Implementers of information processing systems do not have replace well established semantical concepts; they also must deal with as little as irrelevant information to exchange as possible. For example, the information model of the dynamic tariffs data management service for communicating with Aggregators does contain the concept of dynamic pricing, but it does not contain the concept of sensors, with its associated measurements, and units (e.g.: power meter, power measurement, Watt, etc.).

5.4 PATH TOWARDS SEMANTIC INTEROPERABILITY OF DSO INTERFACE

As presented in Chapter 4, the main goal of the DSO Interface is to facilitate the implementation of flexibility and data-driven services, ensuring a standard bi-directional interaction between DSOs legacy systems and market players such as Aggregators, energy communities and ultimately consumers. It also establishes the ground for the interaction with stakeholders such as Data Service Providers that can value both DSO and consumers data.

While DSO systems interoperability has been supported by well accepted standards such as IEC61850 and CIM, there is still work to be done in the interaction with emerging market actors and platforms. In InterConnect, SAREF will be extended to accommodate the services enabled by the DSO interface. However, to ensure the acceptance of the semantics developed within the DSO domain, the services will consider existing standards that cover partially or totally the data exchange between the DSO and the external actor. As shown in Figure 34, the process followed to the sarefization of the DSO Interface services is the following:

1. Describe the key concept of each service of the DSO Interface, main steps and characterization of the data exchange. This has been already presented in Chapter 4 (see section 4.2.2). Further details on the services are described in Deliverable 4.2.
2. Identification of the (standard) information models that already contain totally or partially the data exchange foreseen. For each information model (as already identified in section 5.2) the following is needed:
    a. A specification describing the information model (e.g., scientific paper or deliverable in PDF)
    b. A definition of the information model terms of an ontology in semantic web technology, preferably an URL to a description in RDF. This facilitates the use of ontology matching tools.
    c. A description in XML (if b. is not available), facilitating the transformation to semantic web technology (like OWL) by creating transformation rules.
    d. A description in terms of an UML diagram or any other visualization of the information model (if b and c are not available) to enable T2.4 to create a partial ontology of the required semantical concepts in the information model.
3. The design of a specific InterConnect information model for these services, that is kept as small as possible by only including concepts on a need to have basis.

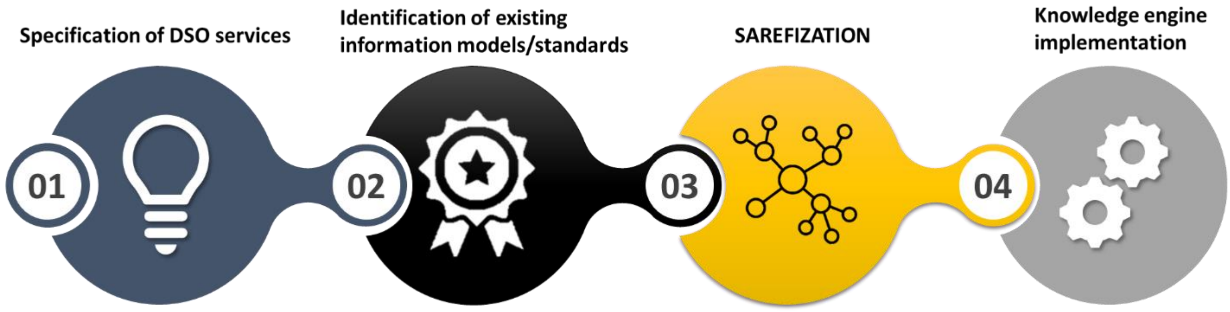

FIGURE 34. INTERCONNECT PATH TOWARDS DSO PLATFORM/ SERVICES SEMANTIC INTEROPERABILITY.

The analysis performed in this chapter allowed to characterize, for each Data Management Service, how much the existing information models are suitable and relevant to support their implementation. Table 29 below summarizes the resulting recommendations, both to select the right information model(s) and, if need be, to extend the selected information model to make it cover all the data to be exchanged. These recommendations will be considered in the data exchange modelling ongoing in task 4.2 and task 4.3.

TABLE 29 – RECOMMENDATIONS FOR DSO INTERFACE IMPLEMENTATION.

Data Management Service	Recommended information models	Gaps to be filled (if any)
Flexibility Procurement data exchange	FlexOffer	Flexibility needs are not supported
	USEF/UFTP	–
	CIM Market	–
	SAREF	Flexibility is not supported by SAREF/SAREF4ENER
Dynamic network tariffs data exchange	SAREF	Tariff related concepts can be found in SAREF for Water (SAREF4WATR). More investigation must be done to check that those concepts can be applied to energy.
	OpenADR	Prosumption plan is not supported
	USEF/UFTP	Power limitation is not supported
	EEBus	Tariff structure is not fully supported yet
	DLMS/COSEM	Prosumption plan is not supported
	CIM / CIM Market	–
Topology and consumer connection information management	CIM	–
	IEC 61850	–
Network observability and grid constraints data exchange	OpenADR	Watchdog/Heartbeat support should be further investigated
	EEBus	Watchdog/Heartbeat support should be further investigated
	DLMS/COSEM	–
	IEC 61850	–
	SAREF	“Network” related concepts are found but more investigation must be done to check that those concepts can be applied to energy.
Open Data and Analytics data exchange service	CIM	–
	SAREF	Anonymized meter data and load profile are not supported
	DLMS/COSEM	–

6. CONCLUSIONS

This deliverable provides the functional specification and architecture of the DSO Interface, which ensures a fully interoperable and replicable interface with new marketplaces and actors.

The DSO plays a key role in the development of a consumer-centric energy system, enabling new standardized flexibility products provided by smart homes, buildings, and communities. However, it can also benefit from the data collected by the HEMS for improved observability and forecasting. The DSO interface concept was developed as part of Interconnect's smart energy reference architecture [71], to ensure a standard interaction between DSOs and energy and non-energy marketplaces, ensuring neutral, transparent, and secure data access to all market players.

The DSO interface will enable the demonstration of InterConnect use cases adopting a standard and replicable interface with the DSO from the different pilots. The main objectives of the platform are the following:

- Allow universal access of DER, microgrids and energy communities in flexibility and energy markets, considering different flexibility market models (including P2P markets).
- Accommodate flexibility services designed according to the needs of the DSO
- Compliance with GDPR
- Cybersecurity

The concept was developed to enable the implementation of relevant flexibility services identified in Chapter 2 that can help manage distribution and transmission grids as well as energy markets, taking as inputs the grid-centric services and use cases from WP1, as well as other relevant European projects and other initiatives.

The DSO Interface will then enable the implementation of these different mechanisms through a standardized approach, for both services, data exchange and communication, also considering the platforms demonstrated in relevant EU H2020 projects such as Interflex, Integrid, Platone and FHP, reviewed in Chapter 3.

The functional architecture proposed in Chapter 4 was designed with a modular approach, allowing for the implementation of the different InterConnect use cases foreseen for the different pilots, but following a common approach. This provides the ground for the technical specification in Task 4.2, where the technical architecture and detailed data modelling will be designed and implemented.

Aiming at full interoperability within Interconnect energy ecosystem and aligned with WP2 semantic interoperability framework, a gap analysis of the applicable ontologies for the exchange of information with the DSO was conducted, on the DSO use case related identification. From the analysis performed, it was clear that the adoption of semantical concepts can contribute to improve interoperability and enable the provision of new energy and non-energy services. However, this exercise should take into consideration current CIM standards 61970/61968/62325 standard series, already established as the most probable standard for TSO and DSO domains and direct interactions (energy and local markets).

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ANNEX 1 - TSO SYSTEM NEEDS AND SERVICES

The TSO is the main responsible for maintaining the security of electricity supply including supply reliability and power quality considering system variabilities, uncertainties, and outages. Several flexibility services are designated to cope with the following phenomena challenging the TSO's security of supply:

1. Energy availability
2. Power capacity (Generation/grid capacity)
3. Reliability of supply (Predictive, corrective, restorative)
4. Power quality (Frequency/voltage waveform, magnitude, and quality)

To this end, Table 30 describes the main characteristics of the TSO flexibility needs.

Based on the flexibility needs, and according to INTERRFACE project, different TSO flexibility services are gathered in

Table **31** as per implemented in different European power systems, and in particular, Horizon 2020 projects (IDE4L, SmartNet, EU-Sysflex and FutureFlow) in addition to the new services that are defined to be implemented in INTERRFACE project.

TABLE 30 - TSO FLEXIBILITY NEEDS IN POWER SYSTEM OPERATION AND PLANNING.

Level	System		Zonal/Local	
Type	Power	Energy	Loading capacity	Voltage
Need	Balancing generation and consumption to maintain frequency stability	Balance of system for consumption states over time	Ability to send power among nodes with local/regional restrictions	To keep the bus voltages within the limits
Basis for higher need	Higher penetration of intermittent resources	More Energy-limited resources in the system	Higher demand/supply peak, higher exploitation	Higher amount of decentralised intermittent DERs
Time vision	Short-term	Medium to long term	Short to medium term	Short term
Activation Timescale	Fractions of a second up to an hour	Hours to several years	Minutes to several hours	Seconds to tens of minutes
Examples of Solutions from system-wide to local level	PSS, POD, FFR, Synthetic Inertia, DSM, ESS	HVDC super grid, Optimization, ESS, Seasonal shifting, Back-up generator, Self-sufficient load	PST, Re-configuration, Re-scheduling, DLR, ESS, DSM	Coordinated voltage control, FACTs, AVR, OLTC, Harmonic damping, End-user voltage conditioning, flicker mitigation, phase balancing

TABLE 31 - FLEXIBILITY SERVICES FOR TSO POWER SYSTEM OPERATION AND PLANNING.

Needs	Services		Definitions
Balancing requirements	**Frequency Response services**	**Frequency Containment Reserves (FCR)**	An automatic function aiming at stabilising the frequency at a steady-state value within the permissible maximum steady-state frequency deviation after disturbances in the high-voltage grid.
		automatic Frequency Restoration Reserve (aFRR)	A centralised automatic function intended to replace FCR and restore the frequency to the target frequency to relive the activated FCR capacity for future needs.
		manual Frequency Restoration Reserve (mFRR)	A manual change in the operation set-points of the reserve (mainly by re-scheduling), in order to restore power balance to the scheduled value and to relive the activated aFRR capacity for future needs.
		Replacement reserves (RR)	Semi-automatic or manual activated reserve to replace the activated FRR and/or complements the FRR activation.
		Fast frequency reserves (FFR)/Synthetic Inertia	Rapid active power increase or decrease by generation or load, in a timeframe of less than 2 seconds, control rate of change of frequency.
	Innovative Frequency Response/quality services	**Ramp control**	A new service that is used to ensure system stability by responding to variations in demand, variable weather forecast errors and plant outages. In a longer timeframe than a traditional FRR reserves.
		Smoothed production	With similarities to mFRR, this service is aimed to adjust start-up time of generation to follow demand schedule more closely (shifting part of production up to 30 minutes from start of one market period to end of market period before it).
		BRP portfolio balancing	BRP by balancing his own position, contributes to the balance of the electricity system.
		Damping of power system oscillations	Dealing with the angle stability of power systems, this service is used to avoid oscillation growing and loss of synchronism. These low-frequency oscillations affect the stability and efficiency of the power system.
		Local Grid Balancing	System Operators, as a part of their neutral market facilitator role, directly or indirectly will be the entities responsible for validation of traded flexibility related to assets connected to the distribution grid. These issues should be solved through cooperation between the system operators and the market parties (aggregators, energy communities, single end-users) responsible for causing the local imbalances.
Congestion management	**Intra-regional**	**Operational/Real-time**	With similarities to mFRR, it is used internally by TSOs / DSOs for congestion management in with

Needs	Services		Definitions
			activation in real-time (during market time unit) manually by a dispatcher.
		Short-term planning	With similarities to mFRR, it is used internally by TSOs / DSOs for congestion management in short-term planning timeframe activated in D-1 by a short-term planner.
		Long-term planning	An envisaged service that may serve network reinforcement deferral, network support during construction and planned maintenance, where location-specific flexibility assets are being activated for shaving or shifting peak demand and production in order to compensate for the lack of network connections, loads or production units mainly in the distribution network.
	Cross-border	**Re-dispatch**	TSOs or DSOs by changing the generation and/or load pattern for example through curtailment, use this service as a remedial action in order to relieve a physical congestion.
		Countertrading	Countertrading means a cross-zonal exchange initiated by system operators between two bidding zones to relieve physical congestion, where the precise generation or load pattern alteration is not predefined. This measure is a market-based solution, where the cheapest bid is selected independently of the geographical location within the bidding zone.
Non frequency ancillary services for voltage control and restoration	**Reactive power and voltage control**	**Obligatory reactive power service (ORPS)**	The main function is to maintain the voltage profile within the acceptable range and within the tolerance margins. This will allow a minimization of power losses and keep a steady state security.
		Enhanced reactive power service (ERPS)	Enhanced reactive power services (ERPS or a like) is voluntary service organised for any service provider, that can absorb or inject reactive power can provide ERPS. Usually, this ancillary service is connected with the mandatory system reactive power services, provided by the TSO.
		Fault-ride through (FRT) capability	FRT is the capability of electric generators to stay connected in short periods of lower electric network voltage (voltage dip) until the faulted element has been cleared from the transmission system.
	System Restoration	**Black Start**	The ability of a power source to support the system restoration after a blackout, through a dedicated auxiliary power source without any external supply.
		Islanding Operation	Utilizing the concept of micro-grid to enhance the network reliability in which the network is islanded from the faulted network after an outage and resynchronized after fault clearance.

Needs	Services		Definitions
Adequacy requirement	**Capacity Remuneration Mechanisms**	**Strategic reserve**	Strategic reserves are essentially generating units that are kept entirely available for emergencies and are called upon by an independent body (e.g., the TSO). It operates only when the market does not provide sufficient capacity to meet the demand.

TSOs and DSOs are mandated to collaborate including exchange of information to facilitate the monitoring and acquisition of flexibility services from DERs connected to the distribution grid in particular, for balancing, voltage regulation, and congestion management, both for local needs and for the entire power system [15]. Therefore, these services and products are briefly discussed and summarised in this report.

Balancing: automatic Frequency Restoration Reserve (aFRR)

Balancing markets include capacity and energy balancing products. TSO is responsible for establishing the balancing markets to procure reserve products such as aFRR, mFRR and RR, as the single buyer of such services. Under some advanced coordination mechanisms, DSO could also support TSO in the balancing responsibilities or even assume some balance responsibilities [16].

The role of FRR energy markets is to return the frequency to its normal range and to restore power balance to the scheduled value. This is ensured by automatic activation of FRR with regulation energy from the aFRR reserve capacity and recovering the aFRR capacity with manually activated mFRR bids.

Balancing capacity markets ensure the capacity needed for the providing the balancing energy needed. While balancing markets used to be organised nationally or regionally, development of PICASSO and MARI and TERRE, as the common aFRR and mFRR and RR service exchange platforms respectively, will empower the European-level exchange of frequency regulation products compensating inter-zonal imbalances and increasing reserve markets liquidity. Table 32 shows some relevant parameters of the aFRR service including the technical specification of the service, and the information of the product being offered.

TABLE 32 - TSO AFRR SERVICE AND PRODUCT PARAMETERS.

Parameter	Description
Product offered	Size: Active power MW) for the delivery time with a minimum bid size Time: the maximum resolution for which the product can be bid into the market (1hour-1Year for capacity and 15min-1hour for energy)
Price	Per Capacity/Energy block accepted/activated for each delivery time (pay as bid, marginal, or regulated)
Reservation and/or activation	Reservation and Activation (pro-rata or merit order) are possible.
Distance to real time (Market unit time or validity period)	Capacity: the time ahead from real time when auction/agreement for the balancing product takes place (typically on daily-basis in EU while may be extended up to a year in some regions) Energy: The time ahead from real time when TSO activates a given product (typically less than 1 min-basis in EU while could be ranged up to 1 hour in some countries)
Mode of activation	Automatic SO signal (AGC signals published every 2-4 s)

Parameter	Description
Expected duration of the response: activation delay	Following NCs, the activation delay must not exceed 30 seconds depending on the mode of activation in use and the local generation structure
Full Activation time	Typically 5 min is the period of time between receipt of a valid instruction by the Activation Optimisation and the end of ramping to meet that instruction. It is ranged from 90s to 15min in EU countries.
Activation purpose (Link to secondary or other services)	Possible to be activated for other purposes than Balancing (e.g. congestion management) in some EU countries
Locational need/ Geographic scope	Product can specify delivery point, but order books are organized according to LFC areas due to technical linking or SO rules
Aggregation	Aggregation allowed
Deactivation period	TSOs consider that the duration of the full activation time is also relevant for deactivation.
Minimum duration of delivery period	15 min seem to be a typical value. Although the duration of the flexibility activation can be the result of the selection of different bids, for simplicity a minimum duration seems to make sense. In any case this is not part of the bid information. It is equal to validity period, typically.
Providers	Generators; Load; Pump Storage; Batteries with minimum technical availability, ramping rate and the connection requirements (agreement needed between TSO and DSO for connected-to-distribution DERs)
Symmetrical product	Does not need to be symmetrical in most EU countries
Congestion risk indicator	(envisioned) It will not be allowed for a BSP to offer flexibility in the congested direction.
Market closure	H-25 min. is typically when bids must be submitted to the energy balancing market.
Divisibility	Possibility for a buyer to use only part of the bids
Market lead time	The minimum period between the market closure and the start of the validity period is typically 25min.

Congestion Management

Balancing supply and demand, acquiring reserve and managing congestion are handled by TSO in a concurrent manner. In line with balancing and reserve, congestion could also be seen as flexibility product for transfer capacity needed in short to medium and long term to transfer power between supply and demand, where local or regional limitations may cause bottlenecks, physically or structurally, outcoming in congestion costs.

Congestion management is any measure originated from TSOs or regulators to influence grid flows and to solve cross-border and intra-zonal violations in both operation and investment stages. It uses different exchange markets (DAM and IDM), products (RR and mFRR) and rules (grid tariffs, contract for balancing capacity and others). Currently, congestion issues of transmission system are mostly alleviated by unit-based dispatching, re-dispatching or countertrading and needs revision to involve DSO, to promote self-dispatching, and to work with common balancing energy markets. Significant Overlap between balancing and congestion management triggered the discussion on removing barriers of a combined balancing and congestion management, for both DSO and TSO.

Different types of flexibility products for congestion management are detailed in Table 33 at intra-zonal and cross-border levels amongst which intra-zonal operational and short-term product parameters are detailed here in relation with InterConnect project's applicability.

TABLE 33 - SERVICE AND PRODUCT PARAMETERS OF TSO OPERATIONAL CONGESTION MANAGEMENT

Parameter	Description
Product offered	Average active power for the delivery time (energy) with minimum resolution in the bid's time and size; Capacity and energy
Price	Per energy block offered/activated for each delivery time (Pay as bid, marginal price, or regulated)
Reservation and/or activation	Reservation and activation possible
Mode of activation	Manually by dispatcher (scheduled and direct activation for mFRRsa and mFRRda products, respectively) Activations for mFRRsa take place 7.5 minutes before delivery and mFRRda can be ordered until 7.5 minutes after (H+) delivery
Expected duration of the response	~5 min. (Can be same as balancing markets, but most likely hours)
Full Activation time	~12.5 min. (Same as balancing markets or different if special products.)
Locational need/ Geographic scope	Product must be location specific
Aggregation	Can be allowed while is restricted as per intra-zones and cross-boarder limits
Deactivation period	TSOs consider that the duration of the full activation time is also relevant for deactivation (agreement between TSO and DSO for connected-to-distribution DERs).
Minimum duration of delivery period	~5 min. (Can be same as balancing markets, but most likely hours)

TABLE 34 - SERVICE AND PRODUCTS PARAMETERS OF TSO SHORT-TERM PLANNING CONGESTION MANAGEMENT

Parameter	Description
Product offered	Average active power for the delivery time (energy) with minimum resolution in the bid's time and size
Price	Per energy block offered/activated for each delivery time (Pay as bid)
Reservation and/or activation	Self-dispatch activation
Mode of activation	Self-dispatch
Expected duration of the response	Not applicable/0min. (Results are known in advance.)
Full Activation time	Not applicable/0min. (Results are known in advance.)
Locational need/ Geographic scope	Underlying resource(s) (and postal code) are indicated in the offer.
Aggregation	Can be allowed while is restricted as per intra-zones and cross-border limits
Deactivation period	Not applicable/0min. (Results are known in advance.)
Minimum duration of delivery period	~15 min. (Can be same as intraday markets, but most likely hours.)

Voltage regulation

Reactive power management is the main tool used by the TSO to regulate voltage in transmission networks. These types of services can be:

- Obligatory, as for example the mandatory reactive power regulation that conventional synchronous generators must very often provide to the TSO.
- Market based, although some frequent concerns arise when dealing with reactive power markets, see for example [17].

As mentioned, obligatory voltage control is usually provided by synchronous generators, power park modules and HVDC converter station. The core legislation is the Network Codes (national regulations aligned with European regulation 2016/631 - Requirements for Generators (RfG)), and the following requirements are considered:

- Article 17 (2) Type B synchronous power-generating modules shall fulfil the following additional requirements relating to voltage stability: (a) regarding reactive power capability, the relevant system operator shall have the right to specify the capability of a synchronous power-generating module to provide reactive power.
- Article 18 (2a) Type C synchronous power-generating modules shall fulfil the following additional requirements in relation to voltage stability: (a) regarding reactive power capability, the relevant system operator may specify supplementary reactive power to be provided.
- Article 20 (2a) Type B power park modules shall fulfil the following additional requirements in relation to voltage stability: (a) regarding reactive power capability, the relevant system operator shall have the right to specify the capability of a power park module to provide reactive power.

In the case of HVDC converter station, current network codes consider that the TSO shall determine whether active power contribution or reactive power contribution shall have priority during low or high voltage operation and during faults for which fault-ride-through capability is required. If priority is given to active power contribution, its provision shall be established within a time from the fault inception as specified by relevant TSO.

Although reactive power management has been mostly implemented as mandatory, there are some market-based mechanisms implemented. For example, National Grid reactive power ancillary service is based in three mechanisms: Obligatory Reactive Power Service (ORPS), Enhanced Reactive Power Service (ERPS) and through Transmission Constraint Management (TCM). Table 35 and

Table **36** present the main characteristics of these products. The TCM consists of a bilateral agreement applied for contracting voltage support from generators to help manage the network in case voltage or thermal constraints are detected.

TABLE 35 - OBLIGATORY REACTIVE POWER SERVICE.

Parameter	Obligatory reactive power service (ORPS)
Product offered	General: generators that are in the transmission system the main providers of reactive power, are able to supply the power with a specific factor, short circuit ratio and range (+/- %) Case in UK: The reactive power provider must: • be capable of supplying their rated power output (MW) at any point between the limits 0.85 power factor lagging and 0.95 power factor leading at the BMU terminals; • have the short circuit ratio of the BMU less than 0.5; • keep the reactive power output under steady state conditions fully available within the voltage range ±5% at 400kV, 275kV, 132kV and lower voltages; • have a continuously acting automatic excitation control system to provide constant terminal voltage control of the BMU without instability over the entire operating range of the BMU.

Price	Option 1 in UK: Payment for the service will start from the date that the reactive capability has been tested and the final mandatory services agreement (MSA) is signed. ORPS is paid via the default payment mechanism. Option 2, as it is in many other EU countries: obligatory for large generators. The prices for the provided MVarh are regulated or even free of charge (in e.g., Denmark, Sweden and Bulgaria, the mandatory service is free of charge).
Reservation and/or activation	Automatic activation for ORPS Instructions for reactive power are normally sent from Operator to the generator via an electronic dispatch logging (EDL) system. Generators are generally instructed to reach a target MVAr level within two minutes. This target will sit within the reactive performance capability of the generator, outlined in their performance chart.
Mode of activation	Self-dispatch
Expected duration of the response	Dependant.
Full Activation time	Fast (e.g. 2 min)
Locational need/ Geographic scope	Needed, service is local dependant.
Aggregation	Not allowed, only in cases, if the provision would be done from more resources, which geographically belong / are connected at the same node.
Deactivation period	Not applicable
Minimum duration of delivery period	Year, months.

The feasibility of local reactive power markets still raises some questions but is expected to become more relevant as the integration of DER increases and replaces conventional synchronous generation that typically ensure this ancillary service. Main concerns are related with the local nature of the voltage regulation problem leading also to a local reactive power market and the low and volatile costs of reactive power provision, that will only be high under contingencies. This is a challenge for the definition of competitive reactive power compensation costs.

Reactive power management between TSO/DSO is also expected, ensuring no flow of reactive power between the systems, or alternatively, a specific quantity defined or required by the TSO for its own grid management. The relevant TSO and the transmission-connected distribution system operator shall agree on a method to carry out this control, to ensure the justified level of security of supply for both parties. For example, [17] describes a local reactive power developed in the EU-SysFlex project for the provision of reactive power from distributed resources to DSO and TSO in a coordinated manner. This framework assumes that, in the absence of TSO reactive power requirements, the available reactive power flexibility can be cleared by the DSO (as market operator) to balance its grid and guarantee a null reactive power exchange at the TSO-DSO connection point. When the TSO requires a specific reactive power at the TSO-DSO connection point, the DSO clears the bids accordingly. It is shown that two different interrelated commodities are being negotiated (capacitive and inductive reactive powers) leading to two different prices. A cost sharing procedure is proposed to allocate the flexibility activation costs between the TSO and the DSO according to their responsibilities and needs.

TABLE 36 - ENHANCED OR NON-OBLIGATORY REACTIVE POWER SERVICE (ERPS).

Parameter	Enhanced or non-obligatory reactive power service (ERPS)
Product offered	All providers with any plant or device/machine which is capable to generate or absorb Reactive Power, under specific power factor, short circuit ratio and range (+/- %). Capacitive and inductive reactive power products may need to be differentiated.
Price	Two prices for capacitive and for inductive reactive power may be needed. Can be based on the marginal costs of providing the service.
Mode of activation	Depending on the time frame, could be automatic or manual based on the committed schedule
Expected duration of the response	Dependant.
Full Activation time	Fast (e.g., 2 min)
Locational need/ Geographic scope	Needed, service is local dependant.
Aggregation	Geographical defined.
Deactivation period	Not applicable
Minimum duration of delivery period	Systems are committed during year, months.

ANNEX 2 - LOCAL ELECTRICITY MARKETS AND FLEXIBILITY PROVISION

As the European Commission is now lifting decentralized renewable energy target to a higher level by inducing accelerations in the development of consumer engagement and empowerment, changes in the electricity market design to truly integrate these new players might be necessary. As of 2021, consumers are (among others) allowed to perform Peer-to-Peer (P2P) energy trading and to collectively manage DER assets. Consumers are therefore allowed to directly settle and share energy among themselves.

Although the EC provided a clear signal to the industry by defining peer-to-peer electricity trading, a lot of uncertainty remains about its transposition to the national regulatory framework within each EU member state. Moreover, there are other similar (regulatory or market) concepts related to P2P trading, such as local energy markets, virtual power plants, or even energy communities, which are possibly relevant for the implementation of consumer-centric electricity markets, and hence peer-to-peer trading in Europe.

This section works to identify the characteristics of P2P energy and flexibility trading, including the following topics:

- Relevant consumer-centric electricity market concepts are identified.
- Different concepts will be examined regarding how they are implemented from a market perspective including:
    - which stakeholders participate, which roles do these stakeholders take-up, how is the market organized and which products are traded, and

- from a system perspective, what are the interactions with the identified concepts and the rest of the system.
- Finally, some attention is devoted to the technological implementation of the different concepts.

IDENTIFICATION OF CONSUMER-CENTRIC ELECTRICITY MARKETS

This section focuses on consumer-centric electricity markets. Consumer-centric electricity markets take a bottom-up perspective in which consumers have decision right on where to buy and sell their electric energy [30]. Among others, one of the main benefits of such markets is that more product differentiation and consumer involvement is possible [31]. There are different ways in which such markets, with different characteristics, can be organized [32].

Generally, however, consumer-centric electricity markets can be put on a scale from unstructured markets to structured markets. In [33] it was introduced the classification of markets depending on its level of centralization. In between are hybrid markets which are a combination of both [30], [32], [34]. Figure 35 shows three different market topologies: from fully decentralized, a community-based market and a hybrid configuration. Confusingly, there does not seem to be agreement on how to "*name*" such markets, which leads to several terms for the same market.

Table 37 gives a summary of the different market structures that are proposed for integrating energy prosumers into the grid and gives an overview of some of the different terms that are given for such markets. Clearly, key differences between different market designs are based on the degree of decentralization of the design.

TABLE 37 - P2P MARKET DESIGNS.

Unstructured consumer-centric electricity markets	
Different terms	Multi-bilateral trade system [31], multi-bilateral economic dispatch [32][37], decentralized peer-to-peer based market [31], full P2P market [30], P2P market [39], [37], unstructured P2P network [34], fully decentralized market [38], P2P model [33].
Suggested definition for InterConnect	Market design in which peers negotiate directly and simultaneously with each other, without centralized supervision, to sell and buy electricity. They agree on how much energy is transferred against a specific price. Peers do not have to reveal sensible information as they only share power and price that they are willing to trade. Their data and privacy are respected. In a real P2P market, multiple agents are negotiating simultaneously with other peers. Any agent is allowed to negotiate with any other agent. Therefore, this model is often also referred to as a multi-bilateral trading model as it contains multi-bilateral agreements between agents. Consequently, each trade yields differentiated electricity prices. Note that this market structure is not putting constraints on the design of the network. Two peers do not need to be physically close to each other.
Structured consumer-centric electricity markets	
Different terms	Community-based market [31][36][30], Pool-based market [37], Community-based economic dispatch [31], structured P2P network [34], prosumer community groups [39], organized prosumer group model [33].
Suggested definition for InterConnect	This market design is relying on a community, managed by a centralized manager that takes up the role of an intermediator by managing the different trades in the community and between the community and the rest of the system. Peers therefore do not know with whom they are trading as this is handled by the community manager. As a result, a coordinated process ensures that all trades are done optimally. Unlike the unstructured consumer-centric electricity markets, the negotiation process is based on common

	agreements on how the energy is collectively handled. Individual peers cannot express individual preferences and a single price is established. A geographical and electrical proximity between peers is also expected according to energy community definition.
Hybrid consumer-centric electricity markets	
Different terms	Nested organization [36], hybrid P2P market [30], Consensus Multi-Bilateral Economic Dispatch [31], Distributed P2P based market [31], hybrid P2P network [34], Compound market, prosumers-to-interconnected-microgrids or prosumer-to-islanded-microgrid [33].
Suggested definition for InterConnect	Hybrid organizations consist of a combination of the previous P2P-unstructured and community-structured market designs. Individual peers or energy collectives can have transactions between themselves, or they can interact with existing markets. On the other hand, there can also be energy collectives with a community manager to oversee trading inside the community. Different energy communities can also be nested inside each other.

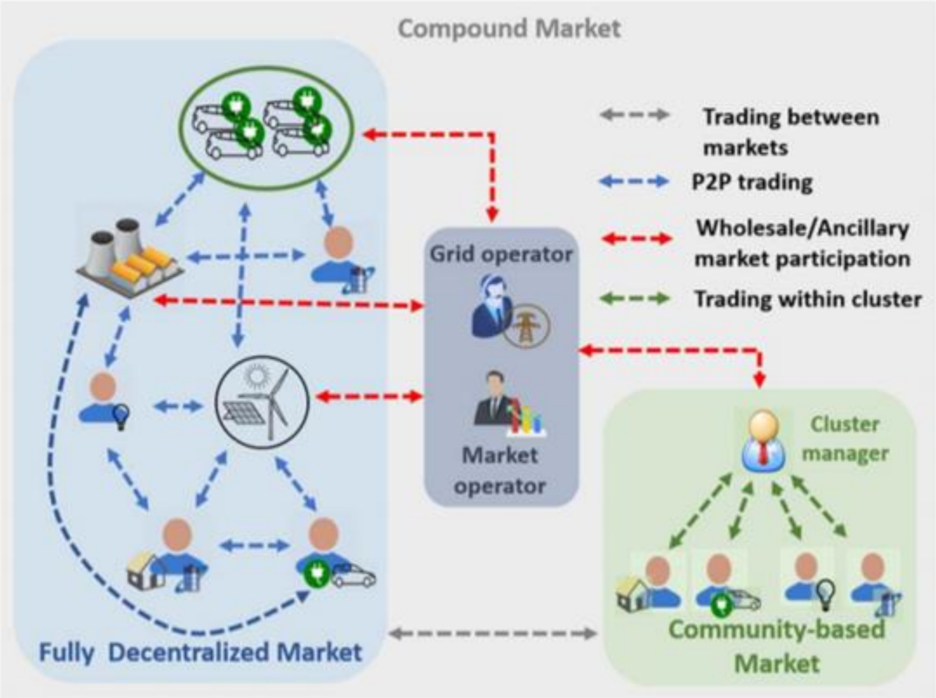

FIGURE 35 - DIFFERENT TYPES OF CONSUMER-CENTRIC MARKET DESIGN TOPOLOGIES [38].

Furthermore, the European concepts have their own legal definitions and, although they fall in the same category as the above broadly defined concepts, they might have slightly different definitions.

MAPPING OF FLEXIBILITY SERVICES TO CONSUMER-CENTRIC ELECTRICITY MARKET DESIGNS

In section 2.2, several different systems are identified and explained, among which:

- Obligations-based capacity remuneration mechanism
- "*Balancing mechanism*", which covers different balancing reserves, from frequency containment reserves to replacement reserves
- Congestion management (named "*local flexibilities*" in 2.3), where according to the section 2.3, congestion management can be organized as
    - smart connection offers, or

- an organized market for congestion management (i.e., for deferral of additional grid investment) with a system operator (DSO or even a TSO) as a single buyer.

In this section, we discuss the suitable identified market organizations for each of these purposes.

For the above definition of peers and consumer-centric market designs, our literature survey discovered no developed concepts for the pure P2P trading concept of different system services. This may be explained by the fact that system operators are natural monopolies for buying the flexibility and are regulated.

No literature was identified on P2P market concepts for capacity remuneration mechanisms. Implementation of such concepts does not seem likely due to several practical constraints, such as a limited number of participants in the market, sufficient trust, and existence of a central entity in charge of system adequacy.

Consumer-centric electricity market concept (including organizations, roles and products) can be envisaged for both, the structured and hybrid P2P markets for all three identified purposes (CRM, balancing, congestion management).

IDENTIFICATION OF ROLES / RESPONSIBILITIES

Chapter 2.1 identifies actors relevant for more centralized flexibility markets. All these actors continue to play an important role in more consumer-centric electricity markets. However, when consumers become more engaged, as explained in section 2.4.1, new market designs require new players that help arranging the market. In Table 38, 4 more specific roles are outlined for consumer-centric markets.

TABLE 38 - ACTOR/ROLES IN CONSUMER-CENTRIC MARKETS.

Market design in which this role is required	Role	Description	Source
Structured, hybrid	Community manager	The Community Manager must ensure common agreements on how the energy collective is to jointly handle its internal objectives and its interaction with the system are ensured.	[35]
Unstructured, structured, hybrid	Peer	A peer can be defined in two ways. The definition is chosen has an influence on the eventual definition of P2P trading. Either a peer is anyone who owns or operates an asset or group of assets (i.e. production, consumption, storage). Or a peer can be defined in a more general way as all potential active agents in the market. In that way, agents who trade on behalf of others while not owning or operating assets, can also be peers. For the purposes of this report, we opt to go for the second, broader definition.	InterConnect; [30]
Structured, hybrid	Energy Community	A group of like-minded peers (prosumers, generators and consumers) that collectively join a community in which all trades are managed by a centralized manager based on common agreements on how energy is collectively handled.	InterConnect

Unstructured, structured, hybrid	Platform manager	An energy ICT professional who manages a platform that connects to devices to perform energy, flexibility, and grid-related services.	InterConnect

TECHNOLOGICAL POSSIBILITIES AND OWNERSHIP STRUCTURES (ENABLERS AND INFRASTRUCTURE)

Before more customer-centric market models can take place, some underlying technological enablers are necessary to ensure the market can be organized (i.e., market participants need to be able to communicate with each other). Technological solutions exist to enable different types of market models.

TABLE 39 - SUMMARY OF P2P ENERGY-TRADING PLATFORM

P2P energy-trading platform models	Description (cited from [32])
Retail supplier platforms	In competitive retail markets, P2P energy-trading platforms are a value-added service supplier can offer to differentiate themselves. Piclo and Vandebron are examples of retail supplier platforms. Allowing prosumers to obtain more value from their DERs should help suppliers retain them as customers. Suppliers can also benefit by gaining better awareness of their customers through their actions in the P2P platform, allowing them to contract more effectively with generators.
Vendor platforms	P2P energy-trading platforms can also be offered by DER vendors to increase the value of their products. Sonnen, a home battery system vendor, is developing a P2P energy-trading platform, sonnenCommunity. P2P energy trading has also been proposed to reduce the charging costs for fleets of electric vehicles.
Microgrid and community platforms	P2P energy-trading platforms offer a new strategy for incentivizing prosumers to support the formation of microgrids and other community energy initiatives. One of the goals of the P2P energy-trading platform being developed for the Brooklyn Microgrid is to help coordinate DERs to maintain continuity of supply if the microgrid is separated from the main grid. Community energy initiatives may be based around a shared resource, or shared objectives, such as reducing local pollution. P2P energy-trading platforms could be used as part of these initiatives to raise awareness and to incentivize local users to support them. The P2P energy trading pilot projects currently underway are focused on OECD power systems, but another potential application could be incentivizing the formation of rural microgrids in developing countries.
Public blockchain platforms	Blockchain smart contracts provide a secure decentralized protocol for managing and executing transactions. The Brooklyn Microgrid's P2P energy-trading platform uses a centralized blockchain to manage transactions. Public blockchain smart contracts have been proposed to allow P2P energy trading between prosumers without requiring a trusted third party. Several technical challenges still need to be overcome, particularly in terms of privacy and the maximum number of transactions per second. It has also been proposed that wholesale and retail markets could be replaced by a public blockchain platform between prosumers, generators, DSOs and the TSO.

Platforms

A rising example of technological enablers are platforms that underlay different consumer-centric market models to ensure that producers and consumers can directly buy and sell electricity and other services from each other [39]. Such platforms exist to facilitate both structured and unstructured consumer-centric models. It should be emphasized that such platforms can help for both P2P, hybrid and community-based market models. They offer a marketplace for peers to trade generated energy and they ensure local generation and demand are matched [40].

It should, however, be noted that different types of platforms exist depending on the ownership of the platform. Platforms can be owned by the DSO, by the end-consumer, by a consortium of prosumers, by an independent power producer or by an energy supplier in a free-market arrangement [41]. Depending on how the platform is owned and operated, the market design on the platform might become centralized. Likewise, [32] give some examples of different platforms collected in.Yet, this summary is not exhaustive.

DATA SHARING NEEDS

P2P market trading process can have very similar phases has described in section 2.3.2. The main difference is on the actors involved, depending on the P2P market topology. The main objective of this section is to identify the potential interaction of the P2P markets with the DSO. As shown in Figure 36, the following interactions can be foreseen:

- DSO assuming the role of smart meter data operator is responsible for providing updated smart metering data. The frequency to which DSO can provide information is dependent on the smart metering communication infrastructure and on processing of data. It is unlikely that smart metering data can be provided in (near) -real time for P2P continuous trading schemes.
- DSO must validate the transactions and/or provide operation limits for the nodes where the peers are connected. This can be ensured for example indirectly through dynamic network tariffs.
- Consumer-centric markets identified can also provide flexibility services to DSOs. In this case, offers can be sent to the DSO directly or through a flexibility market platform.

Regarding market design, the market represented in Figure 36 operates for LV networks as an intraday market, opens D-1 and its gate closes at hour before. This is aligned with DSO network operation, allowing to manage and avoid local congestion and voltage problems resulting from increased RES production or electricity consumption: electric vehicles, heating pumps and higher numbers of electric appliances.

Additionally, the locational information associated to the bids allow to estimate future status of the network, forecasting potential technical problems and designing dynamic network tariffs accordingly.

Considering the technologies identified Table 39, flexibility can be provided by P2P flexibility platforms or VPPs. In this case the baseline is key for the definition of the flexibility requests and is usually based in load and generation forecasts. In a P2P/community trading context these forecasts will likely be provided by the peers themselves. Flexibility information must be provided in a format that facilitates aggregation, optimization within the aggregated flexibility, and disaggregation of the optimal trading decision and corresponding flex activations to the participating peers.

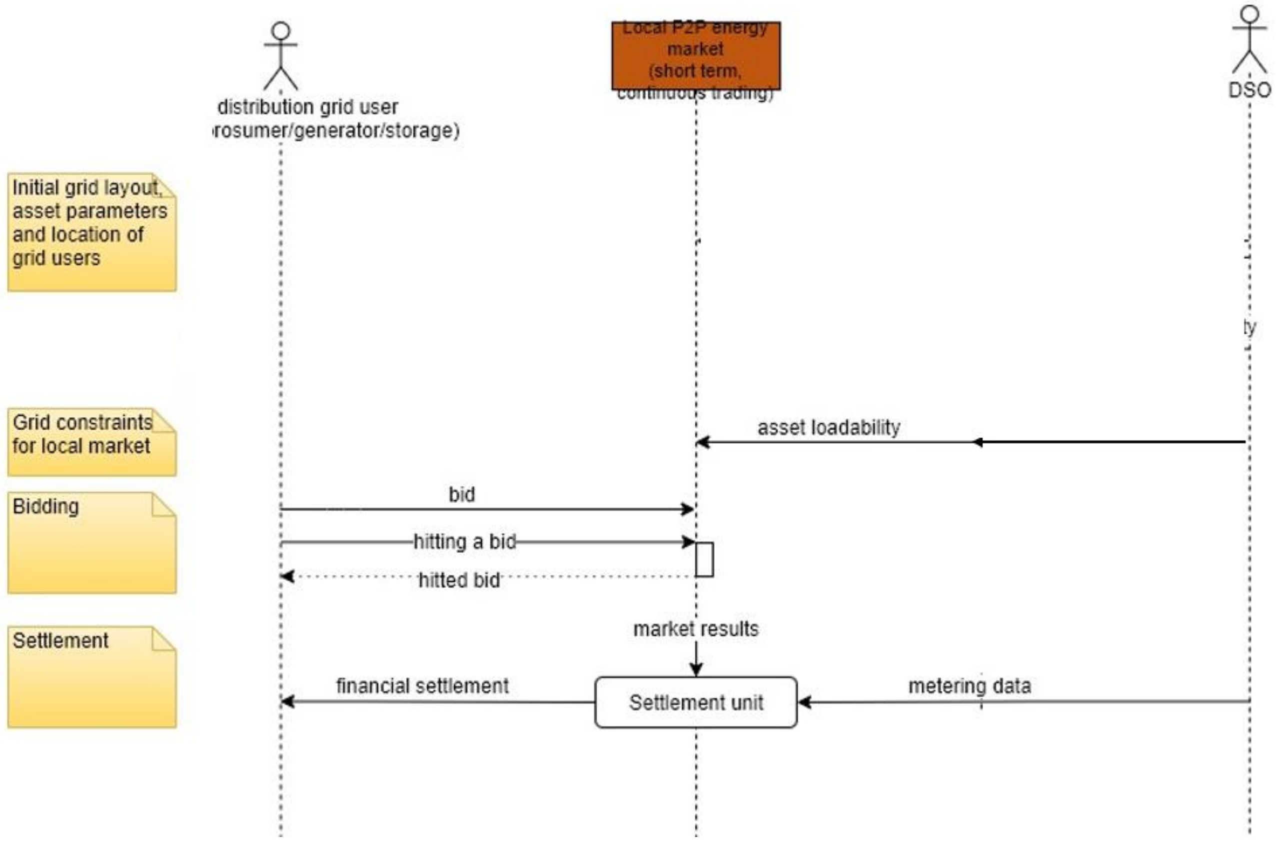

FIGURE 36 - LOCAL P2P ENERGY SHORT-TERM MARKET

ANNEX 3 - USEF AND ENEDIS FLEXIBILITY FRAMEWORKS

This annex describes USEF and ENEDIS flexibility frameworks as a basis for the simplified flexibility framework for the Interconnect project developed in section 2.3.2.

USEF FRAMEWORK

USEF is a market design for the trading of energy flexibility, with a focus on the DSO domain. It unlocks the value of flexible energy use by making it a tradeable commodity and by delivering the market structure and associated rules.

USEF fits on top of most energy market models, extending existing processes to offer the integration of both new and existing energy markets. It is designed to offer fair market access and benefits to all stakeholders and is accessible to anyone internationally. USEF is developed, maintained, and audited by the USEF Foundation, a non-profit partnership of several organizations active in the smart energy industry. For more detail refer to the USEF website (https://www.usef.energy/). This section provides a brief description of USEF framework based in [7].

Energy Flexibility is a cornerstone of USEF. Much more flexibility is needed in the future energy system which will have lots a variable renewable energy to be integrated. Electricity consuming devices and processes like heat pumps, domestic appliances, electric vehicles, HVAC systems, and industrial production processes can offer such flexibility by changing their load profile, known as demand response. USEF defines its own complete roles model that include, among other, aggregators, prosumers and ESCOs (energy service companies). Aggregators can offer various services to actors like TSOs, DSOs, and BRPs.

Conceptual description

USEF created an interaction model that combines the supply value chain interaction model with the flexibility value chain interaction (Figure 37). The roles in the supply value chain are responsible for the supply of energy, and the roles in the flexibility value chain are solely responsible for making use of and creating value through flexibility. The USEF interaction model is depicted below in Figure 37.

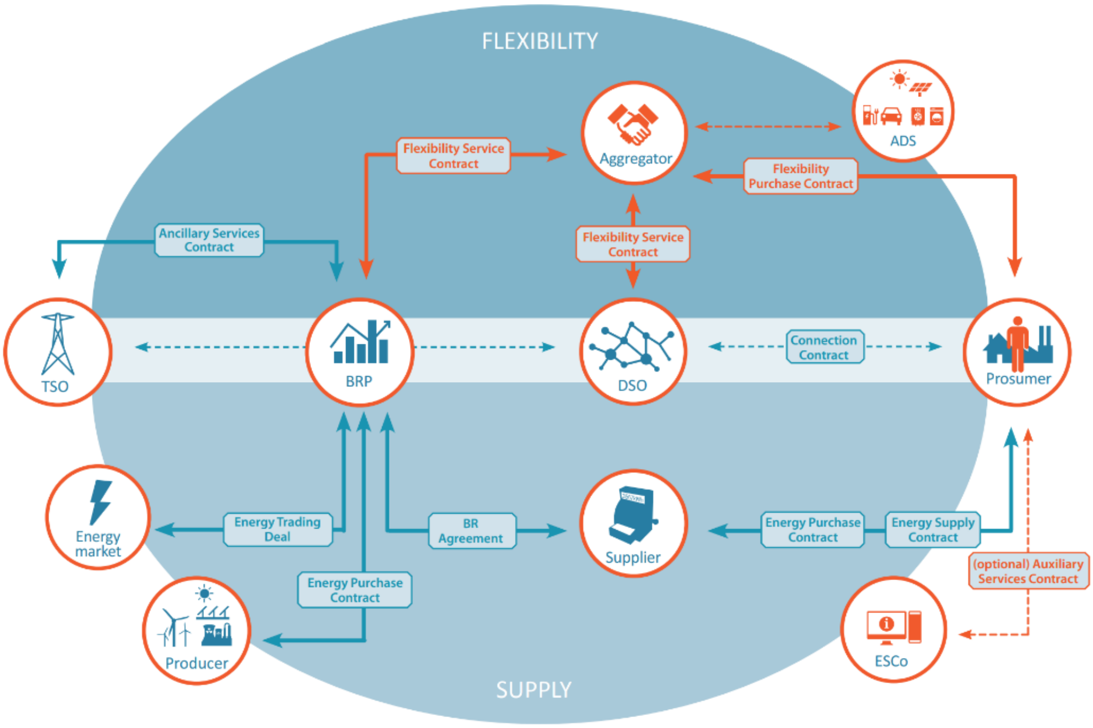

FIGURE 37 - THE USEF INTERACTION MODEL

As can be seen, the USEF interaction model is described based on a detailed role model (rather than actors) with a detailed breakdown. In this model, ADS are the active demand and supply which correspond to the EMS of this document, with the capability of controlling flexible resources. The resources controlled by the ADS are aggregated by an aggregator that can offer them to different flexibility procurers, namely DSO for distribution grid services and BRP to trade this flexibility in commercial bilateral agreements, energy markets, or TSO flexibility markets. In addition, this model recognizes explicitly the need of aggregator and supplier coordination or agreements, since the use of distributed flexibility has an impact on the supplier which sees how his forecasted energy (bought at the energy markets) can be modified by the provision of flexibility by the aggregator, leading to a potential supplier imbalance. A very interesting discussion on the aggregator and supplier coordination models can be found in [8].

Processes

To optimize the value of flexibility across all roles in the system, USEF introduces a market-based coordination mechanism (MCM) along with its processes. The MCM provides all stakeholders with equal access to a smart energy system. To this end, it facilitates the delivery of value propositions (i.e., marketable services) to various market parties without imposing limitations on the diversity and customization of those propositions.

The USEF market coordination mechanism has five phases: Contract, Plan, Validate, Operate and Settle, see Figure 38 for further details and descriptions.

The aim of USEF's Plan and Validate phases is to make optimal use of grid capacity and to maximize all stakeholders' freedom of dispatch and transaction before the actual delivery of energy takes place. The time scales in these phases range all the way from years and months down to just hours before the Operate phase starts. This broad window facilitates trading on different energy markets (such as the forward market, day-ahead spot market, and intraday spot market) and the ability to accommodate changes in the required grid capacity. USEF proposes that the national regulatory authorities determine the details of the gate closure times. A current common practice in energy markets is to close one hour before delivery in the intraday process.

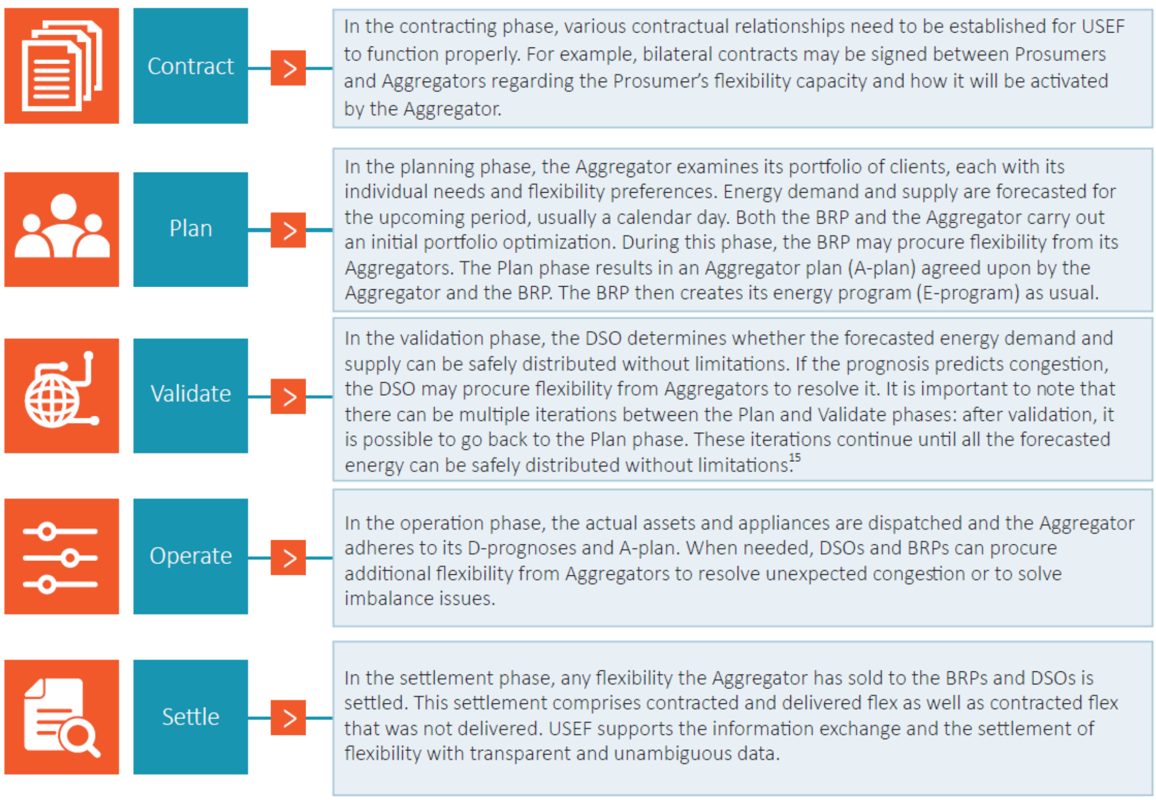

FIGURE 38 - USEF MARKET COORDINATION MECHANISM [7].

Data exchange

To give an overview of the data exchanged in USEF we list here the main information flows of the five phases.

1. **Contract phase**

The contract phase, Figure 39, is when the DSO and aggregators start interacting, and includes the pre-qualification process to check the feasibility of flexibility provision, the information related to the congestion points through the concept of common reference, and bilateral contracts negotiation previous to the market. The common reference is used by the DSO to define the congestion points so that the aggregator can proceed with the right portfolio aggregations according to the grid situation and its flexibility trading options. This common reference is dynamic since the grid situation evolves with time.

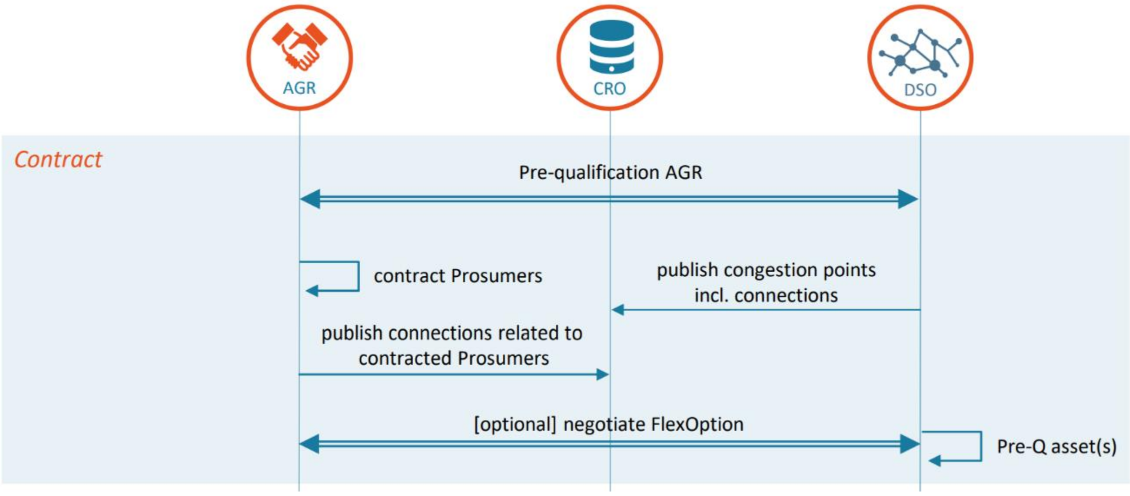

FIGURE 39- GENERAL INFORMATION FLOW IN THE USEF CONTRACT PHASE [7].

2. Plan phase

The plan phase corresponds to the portfolio optimization of the aggregator, according to the congestion points defined in the common reference, to supply its available flexibility to the different markets (BRP and DSO being the procurers, as explained above) to maximize its value. Figure 40 only represents the interactions of the aggregator with the DSO. In case bilateral contract have been agreed between the DSO and the aggregator, the DSO can update the quantity reserved in the contract in case it foresees a lower usage, allowing a further aggregator portfolio optimization.

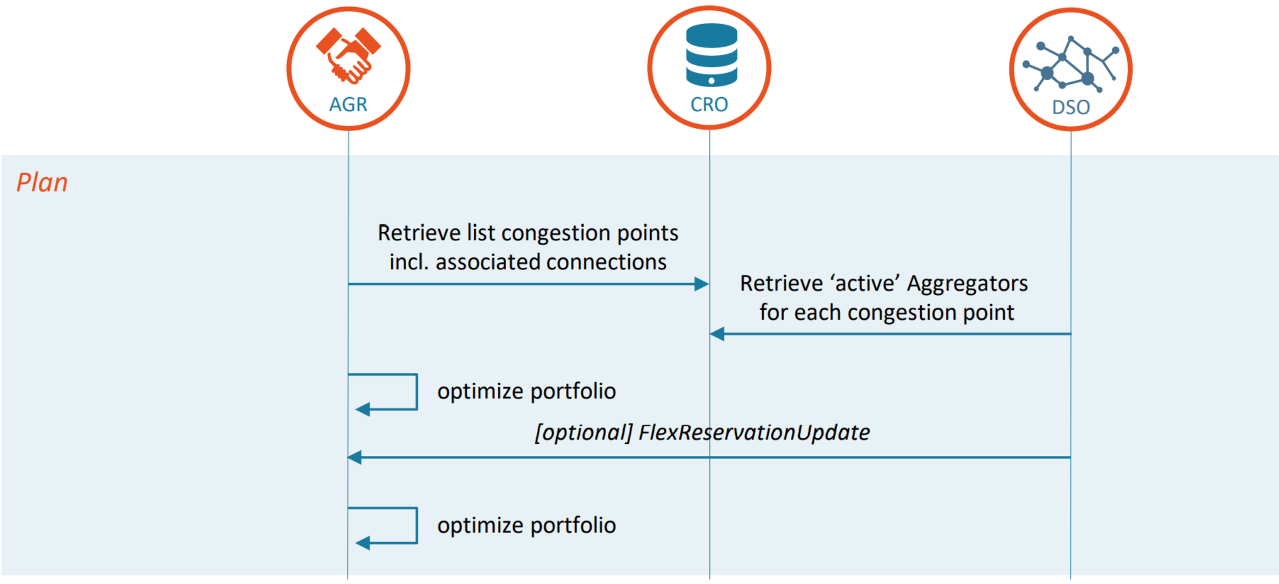

FIGURE 40- GENERAL INFORMATION FLOW IN THE USEF PLAN PHASE [7].

3. Validation phase

The validate phase, Figure 41, allows the DSO to check the grid status based on the aggregator initial baselines (D-prognosis), identify and communicate the potential flexibility needs so that the aggregators can make the corresponding flexibility offers, and the DSO selection of these offers to guarantee the grid safe operation.

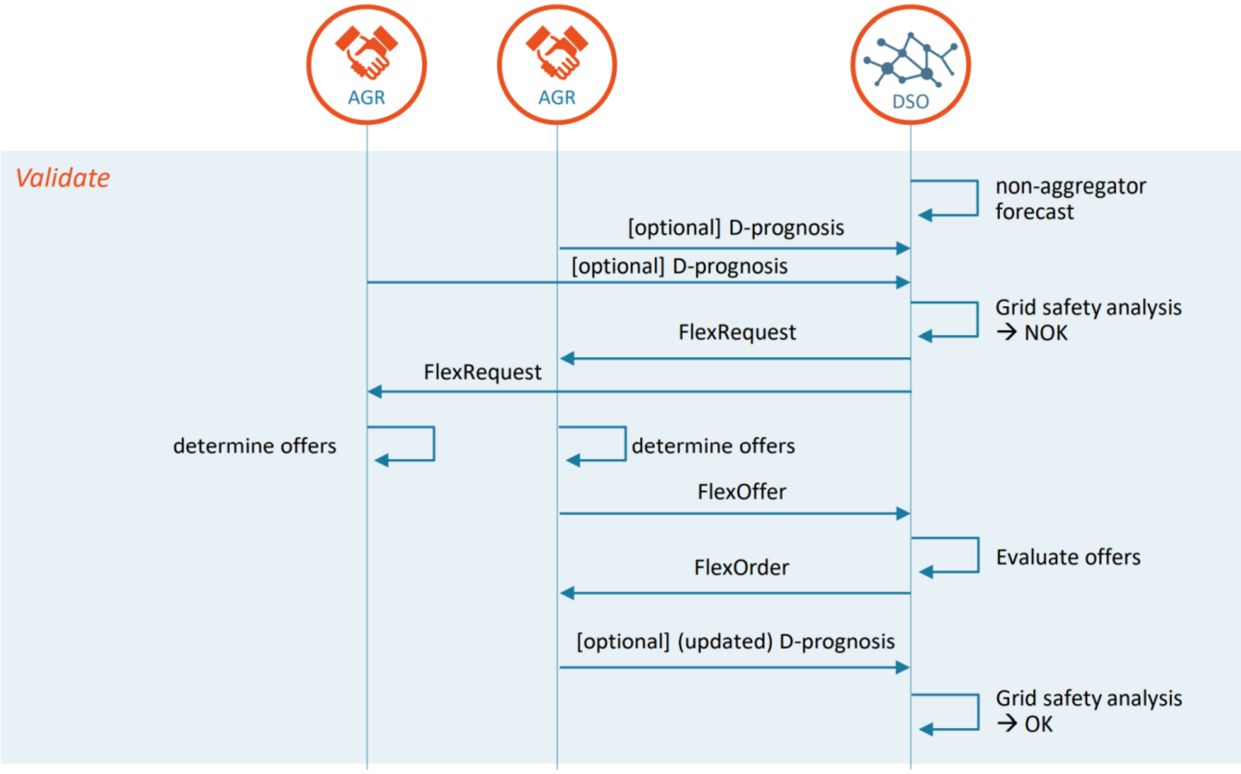

FIGURE 41- GENERAL INFORMATION FLOW IN USEF VALIDATE PHASE [7].

4. Operation phase

In the operate phase, Figure 42, additional flexibility can be activated closer to real time to solve unforeseen problems or flexibility deviations during the previous phases.

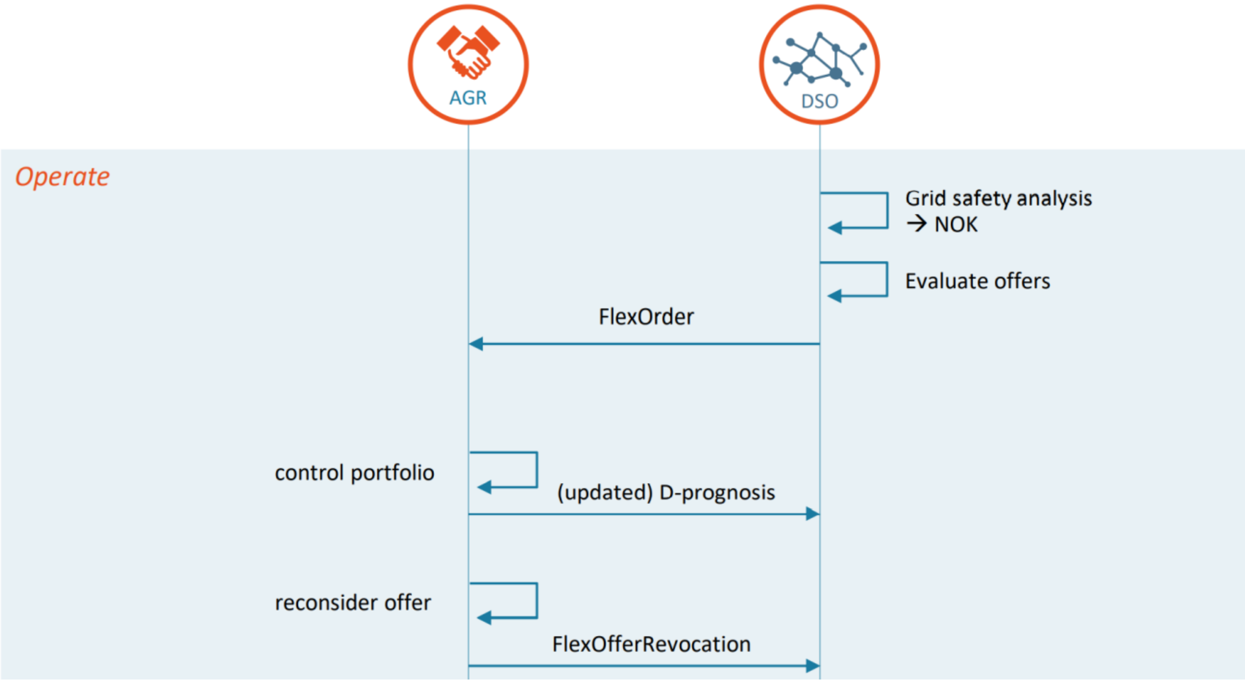

FIGURE 42 - GENERAL INFORMATION FLOWS IN THE USEF OPERATE PHASE [7].

5. Settlement phase

The settle phase, Figure 43, includes the DSO computation and payments of the flexibility committed, and the application of the corresponding penalties in case of deviations of the activated with respect to the committed flexibility.

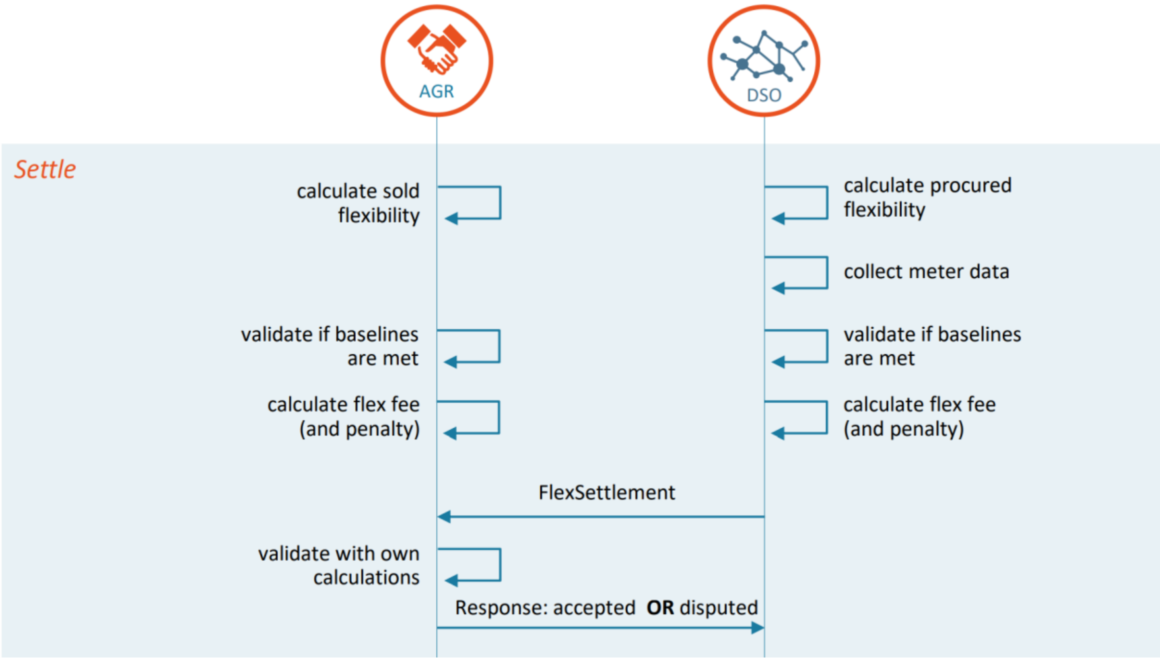

FIGURE 43 - GENERAL INFORMATION FLOW USEF SETTLEMENT PHASE BETWEEN DSO AND AGGREGATOR [7].

FRENCH FLEXIBILITY FRAMEWORK

Today, in France, local flexibility is at the crossroads of many stakeholders' expectations:

- Territorial collective entities anticipating the development of renewable energy and their local value for their area,
- Market players wishing to complement their business model,
- DSOs seeing it as an additional lever for the technical and economic optimization of networks,
- National and European institution (French NRA - CRE, European Commission, etc.) want to increase market players' visibility.

The first use of flexibilities concerns national market mechanisms, to manage supply-demand balance at any time horizon (ancillary services): this is the legal responsibility of the TSO. The use of flexibilities to manage the supply-demand balance has been a reality since the creation of the energy market. The DSO wish to stand as a facilitator for any player wishing to make the most of flexibilities connected to the public distribution network in any of these mechanisms.

Local flexibilities are an additional lever to optimize DSO network planning and operation. Flexibilities compete with the traditional levers of network management and are an opportunity to provide new solutions. However, flexibility studies require a new approach, breaking away from current study methods and tools. Estimating the value of flexibility requires an explicit representation of its impact over time on the grid and a cost-benefit analysis between the use of flexibility and conventional network reinforcement strategies.

The 2 main families of local flexibilities in France are:

1. For an individual benefit, as part of the individual connection:
   a. The Smart (or conditional) Connection Offer is individual, and it is chosen by the customer (consumer or producer) as an alternative to his Reference Connection Offer.
   b. The benefit of this smart connection offer for the customer is a reduction in network connection costs and/or delays.
   c. In return, the customer agrees to temporarily limit its consumption or generation, on demand and without compensation from the distribution system operator.
   d. The customer arbitrates between the reduced connection costs delays and the costs related to the impact of these limitations on its industrial process.
   e. The customer is responsible for considering the consequences of these limitations in his contractual commitments (especially with his Balance Responsible Party).
2. For a collective benefit, in the context of public network development or operations:
   a. Flexibilities constitute a new lever to manage operations or to optimize network design, for the benefit of the community (e.g., the transformation capacity of a primary substation).
   b. Opting for a flexibility service requires that it provides greater value than conventional levers used in network operations or planning, over the timeframe concerned by the flexibility service. The value provided by the flexibility depends on the service offered and on its price.

c. The flexibility offered (i.e., power modulation on demand by the DSO) by one or more grid users and selected by the DSO for a collective benefit must be remunerated.

When flexibility is a technically and economically viable solution against conventional network reinforcement, a local market-based procurement approach is adopted, as explained below.

The tendering of local flexibilities process:

Figure 44 shows the market used by Enedis (French DSO) phases to procure flexibilities (discontinuous market – call for tenders). Table 40 provides a brief description of each step.

FIGURE 44 - FRENCH LOCAL FLEXIBILITY TENDERING PROCESS.

TABLE 40 - FLEXIBILITY TENDERING PROCESSES DESCRIPTION.

Steps	Description
Identification of flexibility opportunities	The DSO identifies the flexibility opportunities (when, where, how much) on its grid.
Request for Interest (optional)	**Publicising areas of opportunity for flexibilities:** The DSO lists these opportunities on a map accessible to any market player y: • description of the service : estimated power requirement, estimated working hours, days of the week and/or weekends, start and end date of the contract (see competitive tendering) • eligible Delivery Points (DPs) in the flexibility areas via a search engine • **Identify potential flexibilities actors in the area:** ENEDIS requests the following non-contractual information from potential aggregators in the area: • General information (name, email, address) • Description of the potential offer (list of delivery point, flexibility type, flexible power activable, activation period) • Such phase enables DSO to assess depth of the market and if needed adjust the flexibility service for the tendering process.
Competitive tendering	In this tender stage, the DSO gives applicants the following information (depending on the cases, applicants may propose different services, DSO opting for the best one(s) from a cost/efficiency analysis): • Location of the opportunity • Direction of the offer • Period • Minimum and maximum duration of the activation • Power level • Mobilisation time • Number of activations of the need (in some cases several activations of the flexibility are necessary) • Ranking criteria to sort offers and award contracts
Contract management	The DSO signs contracts with aggregators which cover the following issues:

Steps	Description
	• Type of contract (with or without capacity reservation) • Price conditions - duration of the contract • Perimeters of eligible sites and process to add/withdraw flexible sites while maintaining validity of the service • Description of the services provided, activation procedure, settlement • Activation tests • Success criteria • Failure criteria • Contract cancellation condition
Activation	The DSO send a signal to aggregators according to the agreed procedure.
Measurement and settlement	To monitor the service provided by the aggregator, the DSO compares the flexibility provided with a reference curve.

In the framework of the Interflex project, a DSO Flexibility Platform was used to interact with aggregators platforms as represented in Figure 45, with the following steps:

1. **Solicitation of a flexibility offer:** The DSO request for offers. This solicitation is transmitted by the platform to the aggregator likely to submit bids for the restricted area.
2. **Submission of an offer:** An aggregator submits a new flexibility offer, spontaneously or following a solicitation. By convention, a new offer is transmitted with an identifier, and with a version number. The data exchanged is described in Table 41.
3. **Modification of an offer:** The aggregator may modify a previously submitted offer. It refers to this offer by its identifier and assigns it a version number higher than the previous value.
4. **Cancellation of an offer:** The aggregator may cancel a previously submitted and non-activated offer.
5. **Reservation request for flexibility offer:** The DSO sends a booking request, which is forwarded to the optimal aggregator (optimal location, offer…). The aggregator sends a return message to the DSO’s platform. The DSO can check, by consulting the platform's GUI, that the aggregator has indeed issued an acknowledgement of receipt of this booking request.
6. **Cancellation of a Flexibility Offer Reservation:** The DSO can cancel an offer booking. The cancellation is transmitted to the aggregator concerned. The aggregator sends a return message to the DSO’s platform. The DSO can check, by consulting the platform's GUI, that the aggregator has indeed issued an acknowledgement of receipt of this reservation cancellation.
7. **Request for activation of flexibility offers:** The DSO sends an activation request, which is forwarded to the relevant aggregator. The aggregator sends a return message to the platform. The DSO can check, by consulting the platform's GUI, that the aggregator has indeed issued an acknowledgement of receipt of this activation request.
8. **Inability to activate flex offer:** In case it’s impossible to activate a resource, the aggregator shall inform the DSO as soon as possible of its inability to deliver the requested flexibility. This message, sent by the aggregator, allows him to signal that an unforeseen event makes it impossible to execute an activation request he has received. In other words, he is no longer able to meet his commitments.

TABLE 41 - DESCRIPTION OF THE DATA EXCHANGE BETWEEN THE AGGREGATOR AND THE DSO.

Category	Information
Header	• Offer ID • Sender • Receiver • Creation date
Power modulation	• Location: ID of the flexibility zone concerned • Offer period • Time interval • Proposed power (in kW) • Associated price (in €/kWh)
Condition of an offer	• Activation Delay, which is the time required to implement a request for activation, in the form of a chronicle. • Minimum authorized activation period • Maximum activation time allowed • Neutralization delay

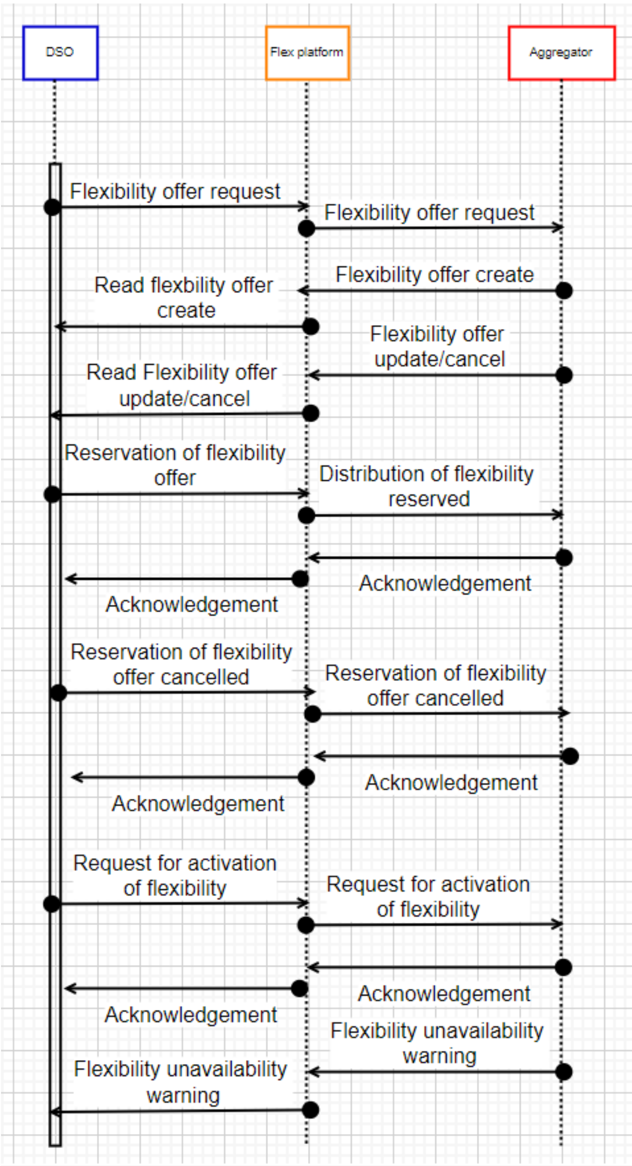

FIGURE 45 - FLEXIBILITY PROCUREMENT PROCESS.

France has one of the most active European markets to value flex on national mechanisms. However, out of Enedis 36 million customers, only ~40 000 customers are involved to date for a combined ~1 GW flexibility. Enedis network has ~2 000 HV/MV substations, ~40 000 HV feeders, and ~800 000 MV/LV transformers. That is, on average, 1 flexible customer per MV feeder, and 1 flexible customer every 20 MV/LV transformer. Of course, flexible sites are not evenly geographically distributed. Even by multiplying customer involvement by 10, which could be consistent within national energy policy target of 6 GW flexibility for national mechanisms (main source of revenue for flexible assets), it seems unlikely to have everywhere and at anytime a liquid flexibility market at LV and even MV levels.
Indeed, considering the 3 types of stakeholders (customers, aggregators, and DSO/TSO), it thus appears:

- Regarding the relationship between customers and aggregators, the time horizon is immediate to aggregate flexibility
- Regarding the relationship between aggregators, national mechanisms and TSO congestion management :
  - the time horizon is immediate, and liquidity and depth is likely at the corresponding TSO spatial scales,
  - simple products may be adequate.
- Regarding the relationship between aggregators and DSO for congestion management, liquidity and depth will not be guaranteed everywhere DSO will want to procure reliable flexibility services, without even considering specificities (localization, power and duration) of DSO flexibility products required to cost-efficiently alleviate the need for alternate classic solutions.

Enedis will keep on providing a framework to foster the development of flexibilities connected to its network, and their valuation on all possible opportunities: it will benefit all stakeholders (customers, market players, TSO) and increase likeliness for Enedis to successfully contract local flexibility services for congestion management.

ANNEX 4 - TSO-DSO COORDINATION

TSO-DSO coordination can take place in many different ways, and each particular market organization and coordination mechanism can have its own specificities depending on countries, regulation, and system operators' needs and structures. However, it is common to simplify TSO-DSO flexibility markets organization and coordination mechanism into several main approaches to understand and identify the main features that differentiate them. Building from existing literature [3], [25], [28] we suggest a further simplification of the main coordination mechanisms by focusing on three main and more common approaches:

- **TSO centralized flexibility market:**
  - It is the approach (see **FIGURE 46**) closer to the current situation, where the flexibility is only procured by the TSO in a unique centralized market, where aggregated DER are also allowed to participate under certain conditions.
  - A pre-qualification process of the DER can take place to guarantee that their activation does not put the DSO grid in trouble, and a DSO validation before the

flexibility activation can also take place, close to real-time, to guarantee the DSO grid safe operation.

- **Local (DSO) and global (TSO) flexibility markets**
  - In this approach, the flexibility offered by the DER is managed in a local DSO flexibility market, while TSO has its own flexibility market(s).
  - The DSO uses the local resources for its own flexibility needs, and the remaining flexibility is made available to the TSO, with two possible sharing mechanisms:
    a) The TSO has direct access to the bids (**FIGURE 47**) so it can directly select those bids that solve its needs in the most efficient way. Under this approach, the DSO may want to validate the bids selected by the TSO before their activation to guarantee its own grid safe operation.
    b) As an alternative, the TSO can agree with the DSO (**FIGURE 48**) the desired flexibility at the TSO-DSO connection points, and the DSO manages its local market for its own purposes but to also satisfy, as possible, the TSO needs according to the agreed flexibility profile.
- **Common TSO-DSO flexibility market**
  - This approach is based on a unique flexibility market where all the flexibility providers can send their bids to be selected by the TSO and DSO.
  - The selection of these bids by DSO and TSO is carried out in a coordinated process, with many possible levels of complexity, and should take into account the constraints of all the grids involved.
  - If the resources are used to resolve grid constraints, the TSO or DSO needs their locational information.

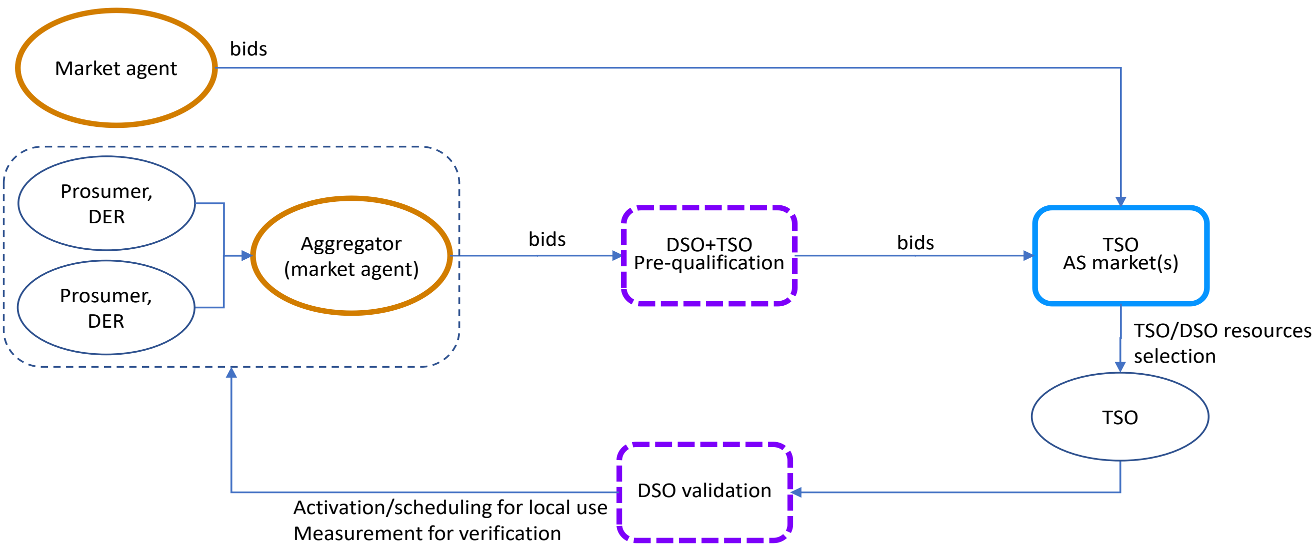

FIGURE 46 - CENTRALIZED TSO FLEXIBILITY MARKET

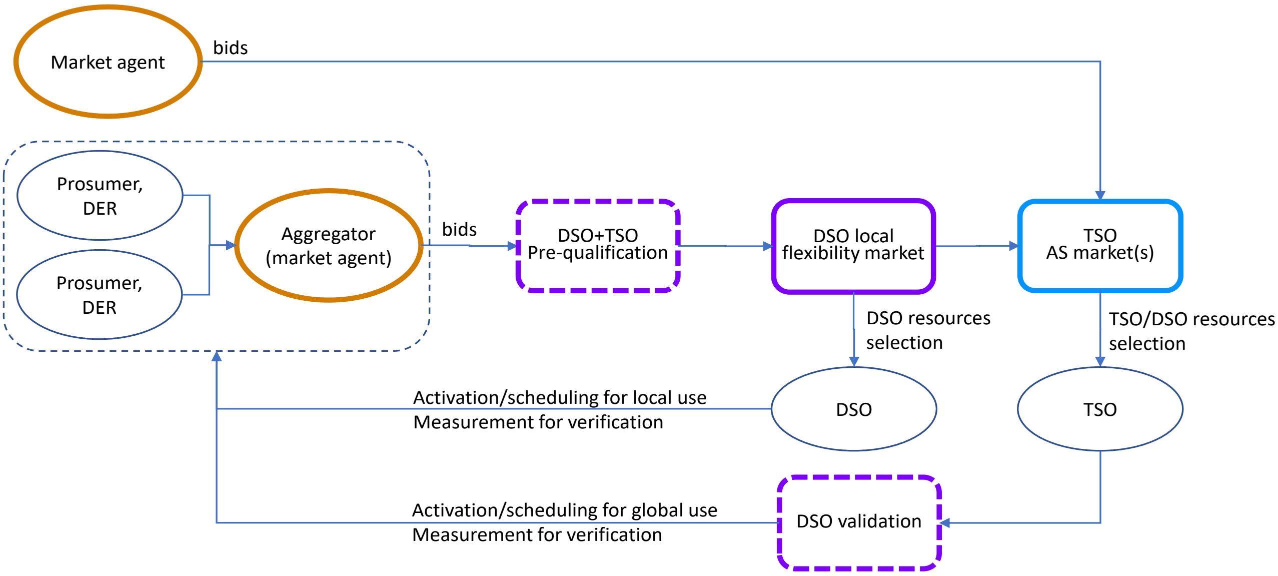

FIGURE 47 - LOCAL (DSO) AND GLOBAL (TSO) FLEXIBILITY MARKETS WITH RESOURCES SHARING

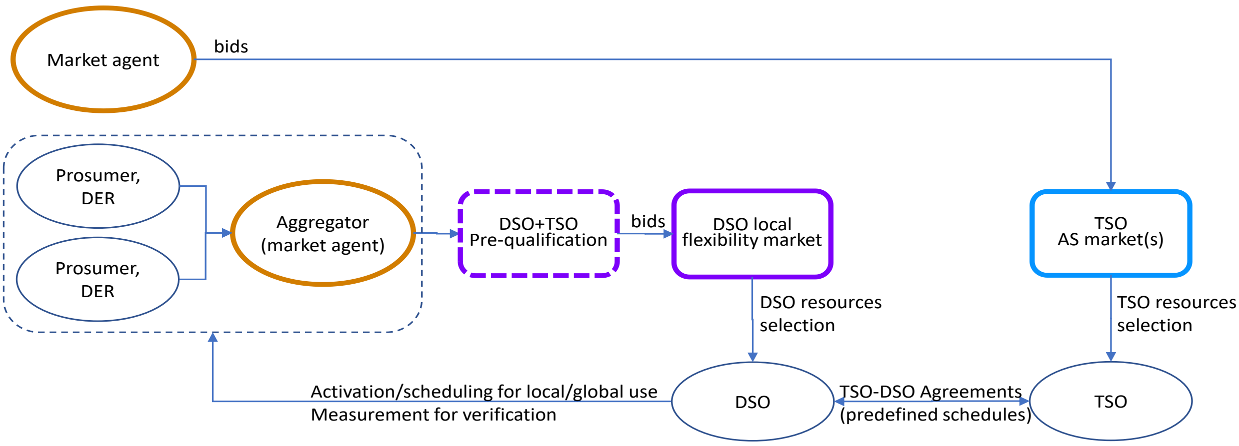

FIGURE 48 - LOCAL (DSO) AND GLOBAL (TSO) FLEXIBILITY MARKETS WITH SHARED RESPONSIBILITY

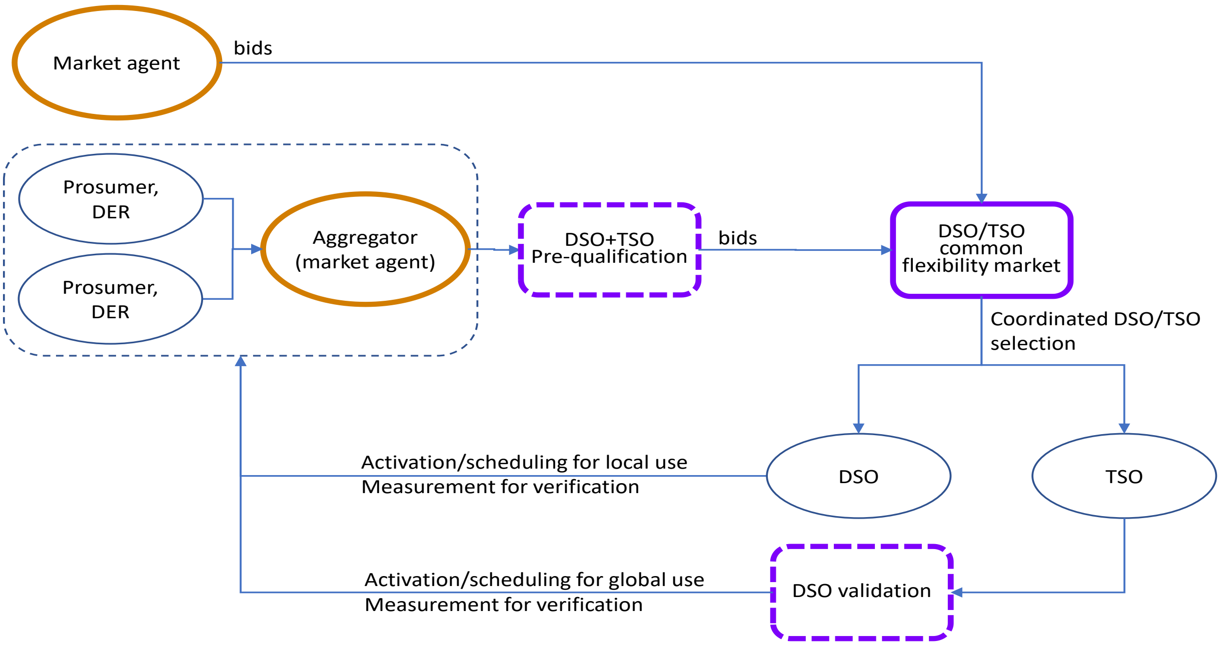

FIGURE 49 - LOCAL (DSO) AND GLOBAL (TSO) FLEXIBILITY MARKETS