one network for Europe

Overview of market designs for the procurement of system services by DSOs and TSOs

D3.1

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About OneNet

OneNet will provide a seamless integration of all the actors in the electricity network across Europe to create the conditions for a synergistic operation that optimises the overall energy system while creating an open and fair market structure.

The project OneNet (One Network for Europe) is funded through the EU's eighth Framework Programme Horizon 2020. It is titled "TSO – DSO Consumer: Large-scale demonstrators of innovative system services through demand response, storage and small-scale (RES) generation" and responds to the call "Building a low-carbon, climate resilient future (LC)".

While the electrical grid is moving from being fully centralised to a highly decentralised system, grid operators have to adapt to this changing environment and adjust their current business model to accommodate faster reactions and adaptive flexibility. This is an unprecedented challenge requiring an unprecedented solution. For this reason, the two major associations of grid operators in Europe, ENTSO-E and EDSO, have activated their members to put together a unique consortium.

OneNet will see the participation of a consortium of over 70 partners[1].

The key elements of the project are:

1. Definition of a common market design for Europe: this means standardised products and key parameters for system services which aim at the coordination of all actors, from grid operators to customers;
2. Definition of a Common IT Architecture and Common IT Interfaces: this means not trying to create a single IT platform for all the products but enabling an open architecture of interactions among several platforms so that anybody can join any market across Europe; and
3. Large-scale demonstrators to implement and showcase the scalable solutions developed throughout the project. These demonstrators are organised in four clusters coming to include countries in every region of Europe and testing innovative use cases never validated before.

[1] The OneNet project partners are listed at: https://onenet-project.eu/partners/

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List of Abbreviations and Acronyms

Acronym	Meaning
A	Availability
aFRR	automatic Frequency Restoration Reserves
BESS	Battery Energy Storage System
BUC	Business Use Case
CARD	Dynamic connection agreement DSO
CART	Dynamic connection agreement TSO
CM	Congestion Management
D	Distribution
DA	Day-Ahead
DER	Distributed Energy Resources
DSO	Distribution System Operator
DSR	Demand Side Response
E	Energy
EHV	Extra High Voltage
FCR	Frequency Containment Reserves
FSP	Flexibility Service Provider
GOT	Gate Opening Time
GCT	Gate Closure Time
HV	High Voltage
I	Electric current
ID	Intraday
IMO	Independent Market Operator
IT	Information Technology
LT	Long Term
LV	Low Voltage
mFRR	manual Frequency Restoration Reserves
MO	Market Operator
MV	Medium Voltage
NA	Non-Applicable
NRT	Near-Real-Time
OO	Optimization Operator
OTC	Over-the-counter
P	Active Power
PPA	Power Purchase Agreement
PQ	Active and Reactive power

Q	Reactive Power
SO	System Operator: either TSO or DSO
ST	Short-Term
STAR	System for Traceability of Renewable Activations
T	Transmission
TD	Transmission and Distribution
TSO	Transmission System Operator
V	Voltage
VC	Voltage control
WA	Week-Ahead
WP	Work Package
WTP	Willingness to pay

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Executive Summary

The ongoing energy transition requires profound changes in the operation of the electric power system. The decarbonisation of the electricity supply requires pursuing renewable energy generation and energy efficiency. In a decarbonisation scenario, all the resources connected to the power system have to be flexible, adapting their electricity generation or demand level according to the energy availability to increase the hosting capacity of intermittent energy sources and maximise the use of the available resources and infrastructures. Therefore, the energy transition makes imperative the adoption of more interactive electric power system operation strategies. In this context, the project OneNet aims at creating the conditions for a new generation of grid services able to fully exploit demand response, storage and distributed generation while creating fair, transparent and open conditions for the consumer. As a result, while creating one network for Europe, the project aims to build a customer-centric approach to grid operation. This ambitious view is achieved by proposing new markets, products and services and creating a unique IT architecture.

Designing an efficient, integrated, and scalable market for the procurement of system services requires taking advantage of the lessons learnt from previous projects on developing the provision of flexibility by third-party assets. Therefore, previous European projects are analysed to study the already adopted coordination models, market concepts and set-ups. The main objective is to provide an overview of the market design aspects of the schemes in these projects and highlight the current gaps. The projects' analysis firstly focused on the key elements of the flexibility mechanisms: actors involved, system services, procurement method, coordination schemes, and grid constraints inclusion. The quantitative project review highlighted the existing large variety of formalisations and set-ups that have been designed, proposed, adopted, and tested for flexibility procurement. The project review highlights that a unique way of general validity to procure flexibility does not exist. Boundary conditions may influence the set-up choices; however, market-based procurement through flexibility markets involving DSO, TSO, or both, in an auction mechanism is of primary interest. The project review also underlined the need for a standardised or, at least, harmonised vocabulary in the context of flexibility procurement. The second stage of the project review contributes to the need for harmonised concepts and vocabulary by classifying the reviewed use cases through a systematic approach. This activity allows to identify the similarities and differences among the reviewed use cases considering a set of aspects useful for describing the adopted market model framework and the interaction among the actors involved.

The development and design of efficient, integrated, and scalable markets are assisted in this deliverable by proposing a theoretical market framework for existing and novel market design options is developed to clearly and precisely categorise market concepts and ease the communication on these concepts both within the OneNet project and externally. Therefore, to develop a framework that is clear and concise, the proposal is limited within OneNet to those mechanisms to provide system services only (i.e. no energy markets), those mechanisms where TSOs and DSOs are the primary buyers of system services, and market-based mechanism

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only (i.e. bilateral transaction, auction market, exchange market). The framework consists of five main pillars, which in turn are composed of different features. Formalising the theoretical market architecture required first to define the reference model for the market architecture that is considered as formed by submarkets that interact. An interaction exists between two submarkets that are somehow linked. The interactions between the couples of submarkets define the model of the whole market architecture. The contribution of the theoretical market architecture is twofold: it represents a descriptive tool able to effectively describe all the elements of a market architecture which involve flexibility; furthermore, it represents a valuable prescriptive tool to be used for designing flexibility markets and their integration with the existing electricity markets. These five main pillars are (i) entire market architecture, (ii) sub-market coordination, (iii) market optimization, (iv) market operation, and (v) grid constraints representation. The first two pillars set up the structure of the entire market and define the nature of the coordination, while the last three pillars describe the dimensions of market clearing. Some features in these pillars are applied to the entire market to represent how the coordination and integration can increase, while other features apply to the individual submarkets. By going through each of the pillars and selecting, for each feature, the desired attribute, the flexibility market can be designed considering the context requirements. The framework is used to describe the market design used by the demonstrators in the OneNet clusters and serve as a basis for the subsequent tasks within WP3, where, amongst others, a gap analysis will take place to be able to move from isolated markets to integrated, scalable and coordinated markets.

One of the peculiar aspects of OneNet 3.1 activities is the strong involvement of the OneNet demonstrators to encourage the flexibility market design process. Several interactions with the OneNet demonstrators were carried out through virtual workshops and questionnaires to take advantage of the field experience and provide the proof-of-concept for the proposed theoretical market framework. Based on the theoretical market framework, the analysis of the OneNet demonstrator and the mapping of the market design highlighted the main challenges of flexibility market design and the integration of the existing submarkets.

The proposed theoretical market framework is applied to the different clusters of OneNet (Northern, Southern, Western, Eastern) in which multiple demonstrators define market designs based on the goal of the demonstrator activities, specificities of each country, considered products, and the interactions between the actors. Within each of the CoordiNet clusters, the demonstrators propose different market designs to be implemented. The OneNet project clusters are re-clustered into three main sets to ease the analysis between comparable market frameworks considering the type of coordination on which the activity focus: market-based TSO-DSO coordination, DSO market-based coordination, technical-based TSO-DSO coordination. The demonstrators focused on the market-based TSO-DSO coordination adopt a coordination scheme in which the TSO and the DSO are coordinated through a market. The flexibility is allocated between the system operators through market-based processes. The OneNet demonstrators that belong to the DSO market-based coordination category focus on the market mechanisms to procure system services from FSPs to solve local needs. To test the DSO coordination, the demonstrators adopt a local market in which the DSO has exclusive

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access to DERs. Even if the interaction with the TSO is not tested by the demonstrators belonging to this cluster, this interaction is considered in the theoretical design of the technical or market-based coordination. The demonstrators that belong to the technical-based TSO-DSO coordination adopt a coordination scheme in which the TSO and DSO directly interact by exchanging information and requests for operating actions. The flexibility is allocated between the system operators employing technical procedures (e.g., interaction between control centres and platforms). Finally, a cross-demonstrator comparison at the submarket level and the coordination between the submarkets is presented. The re-clustering of the OneNet demonstrators according to the type of interaction tested is depicted in Figure 0-1.

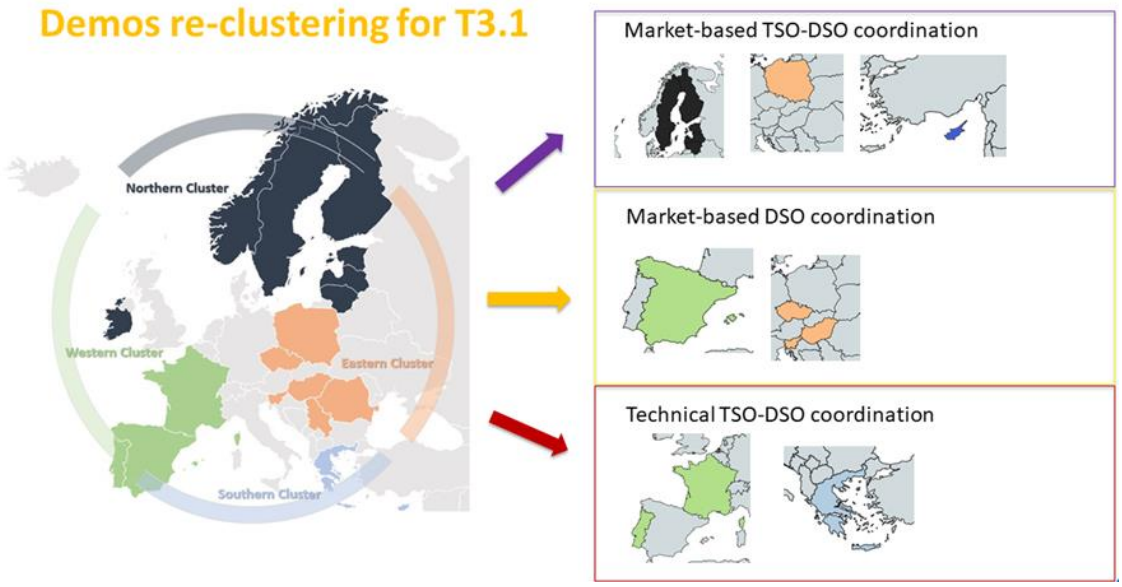

Figure 0-1. From geographical clustering to market design demonstrators' clustering

The mapping of the theoretical framework to the OneNet demonstrators highlighted similarities and differences among the different market designs, contributing to the understanding of the OneNet demonstrators' market framework proposals. Mapping the OneNet demonstrators according to the theoretical market framework highlighted several challenges regarding the design of flexibility markets and their introduction in the existing electricity markets. In flexibility market design, it is of primary importance to define the temporal and locational dimension of the procurement, the interactions within the flexibility submarkets, allocation of flexibility among submarkets. The OneNet Task 3.1 activities point out that the definition of the temporal and locational dimension of the procurement of flexibility is a critical design phase since it influences the market liquidity, the procedures for power system operation, and the FSPs availability. The analysis of the interaction among submarkets belonging to the same market architecture pointed out that bid forwarding between submarkets that both trade activation and availability is a critical aspect. As a consequence, determining the allocation principle of flexibility becomes challenging. It represents an essential aspect since the optimal integration of the flexibility markets in the existing electricity market structure is achieved if the

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flexible resources are efficiently allocated among the different submarkets. The coordination among different flexibility submarket and the impact on the system operation has to be carefully designed to prevent the issues. These kinds of impacts can be classified considering if the flexibility provision simultaneously fills different needs or, on the opposite side, creates problems to the system operation and thus creates a new need for system service. Moreover, it is worth highlighting the significance of the baselining activity to prevent gaming; the market architecture has to avoid speculative behaviours across the various submarkets in which an FSP can participate.

In conclusion, the present deliverable contributes to 1) the identification of state of the art considering the lessons learnt from the previous projects related to coordination models and market set-ups; 2) harmonising flexibility market concepts and the related vocabulary through the use of a systematic market analysis procedure; 3) a proposal of a theoretical market framework for innovative market designs options; 4) the application of the theoretical market framework to the OneNet demonstrators to contribute to the development of flexibility markets and identify the main differences among the proposals and the market integration challenges. The highlighted challenges and gaps related to market distortions and inefficiencies which could arise in integrated flexibility markets are of interest for the further activities of the OneNet project.

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1 Introduction

The ongoing energy transition triggered by the concerns related to the tremendous consequences of extreme weather events caused by climate change requires profound changes in the operation of the electric power system [1]–[3]. The decarbonisation of the electricity supply requires increasing the electrical energy generated by renewable resources and pursuing energy efficiency [2]. In a decarbonisation scenario, an increased presence of intermittent energy sources in the power system and the need for maximising the use of the available resources and infrastructure make it imperative to abandon the traditional load following paradigm favouring a more interactive operation of the electric power system [4]. In this context, all the resources connected to the power system have to be flexible, adapting their electricity generation or demand level according to the needs of the power system operation. This requires addressing the power system transformation at a reasonable cost, without harming the security and quality of the electricity supply, unlocking the potential flexibility of the already available resources, and fostering the availability of new resources [5]–[7].

In this context, the OneNet project aims at creating the conditions for a new generation of system services able to fully exploit demand response, storage and distributed generation while creating fair, transparent and open conditions for the consumer. As a result, while creating one network for Europe, the project aims to build a customer-centric approach to grid operation. This ambitious view is achieved by proposing new markets, products and services and creating a unique IT architecture.

The present deliverable is part of the Work Package 3 (WP3) contribution to the OneNet project. Figure 1-1 depicts the interconnection existing between the OneNet Task 3.1 and other tasks and work packages in the OneNet project. OneNet WP3 is entitled “Integrated and coordinated markets for OneNet”. The overall objective of WP3 is to design efficient, integrated, coordinated and scalable markets for the procurement of system services by DSOs and TSOs. WP3 aims to define a theoretical market framework for innovative market designs options (Task 3.1), study market integration aspects and interrelations of new market mechanisms with existing energy and flexibility markets (Task 3.2), analyse potential market distortions and inefficiencies of integrated markets (Task 3.3) and ensure alignment between developed concepts of market design, the regulatory framework and the demonstrations within OneNet (Task 3.4). Finally, WP3 provides recommendations for the OneNet roadmap.

Task 3.1 ‘Framework for coordination models and market set-ups’ is the first task of WP3. It starts from the best practices and project review from Task 2.1. Task 3.1, that runs in parallel with Task 2.2, focuses on the market design aspects of system services and Task 2.2 on the corresponding product design analysis for system services. Input from the different demonstration clusters is captured and applied to the theoretical framework developed in Task 3.1. The output of Task 3.1, in particular the design of market concepts for the demonstrations, is feed into the task on business use cases (Task 2.3) and it forms the basis of the gap analysis to move from isolated to integrated markets (Task 3.2).

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The present deliverable describes the Task 3.1 activities of OneNet WP3 that aim to contribute to setting the basis for improving the evolution of electricity markets in Europe by reviewing previous works (Sub-Task 3.1.1) and proposing a theoretical framework for innovative flexibility market designs (Sub-Task 3.1.2). This framework is then mapped with OneNet demonstrators' expectations to contribute to the definition of the building blocks for the demonstrator activities and, more importantly, to provide recommendations on the design of the European market (Sub-Task 3.1.3). OneNet task 3.1 and the present deliverable has a strong relationship with work package 2 and in particular with tasks 2.1 and 2.2 that have produced the deliverables:

D2.1 – Review on markets and platforms in related activities.

D2.2 – A set of standardised products for system services in the TSO-DSO-consumer value chain.

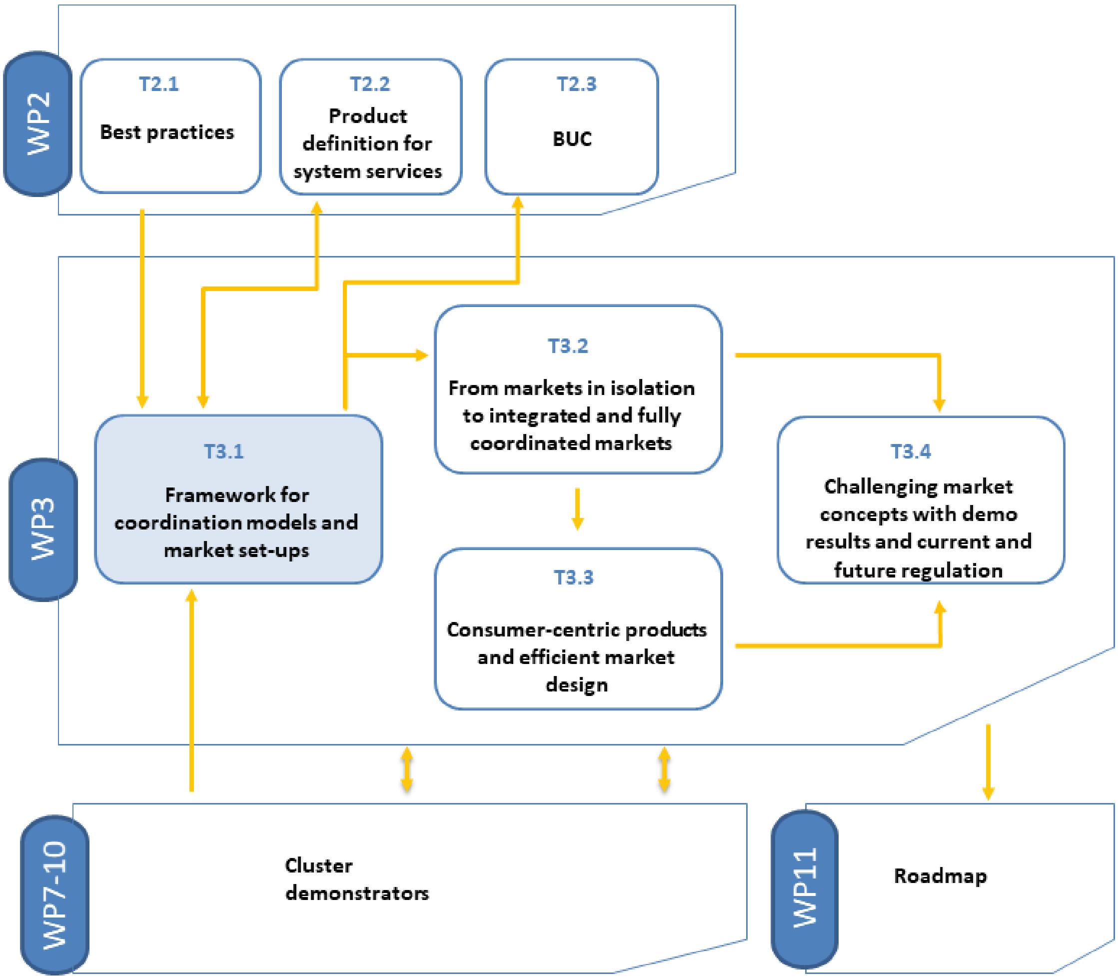

Figure 1-1. Interconnection between the OneNet Task 3.1 with other tasks and work packages in the OneNet project

Flexibility, understood as the ability or willingness to modify power injections and withdrawals to support the system operation, is considered a cost-effective measure to counteract the variability and uncertainty introduced in the power system by renewable energy sources and new loads [8]. Flexibility usage and the provision of system services[2] may represent an alternative to network reinforcements since it allows to reduce or indefinitely defer network investments [4], [13], [14]. Flexibility and the provision of system services can balance electric energy supply and demand at any timescale, both in regular and emergency operation, efficiently dealing with the variability of loads and generation and improving system resiliency [6], [8]. Therefore, the context of the ongoing energy transition, a more secure, resilient, affordable, and sustainable power system flexibility is achieved [6].

Several layers are necessary to enable the provision of flexibility by the resources: the technical and infrastructural layer concerns the hardware and infrastructure involved; the market layer concerns the technical and business rules applied; the institutional and regulatory layer refers to the policy goals and the definition of the roles and responsibilities of the actors involved [5], [6]. Procuring flexibility using the third-party-owned resources connected to the power system calls for dedicated mechanisms integrated within the existing electricity market architecture. In a liberalised electricity sector, the operation of the transmission and distribution systems is considered a natural monopoly entrusted to regulated entities, the transmission, and the distribution system operator (TSO and DSO, respectively) [15]. Both transmission and distribution systems can be divided into several areas operated by the relevant system operator. One or more TSOs can operate the transmission system in a country; each TSO is responsible for operating the corresponding part of the transmission system and the system balancing. Similarly, considering the country's distribution system, it can be formed by several areas operated by different DSOs. In general, the role of both the TSO and the DSO is to operate the respective part of the power system ensuring the reliability of the electricity supply and providing non-discriminatory network access to third parties [5], [11], [16]–[18]. The operation of the power system requires coordinating the grid use and solving expected and unexpected grid problems. To operate the grid, the

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[2] As indicated in Deliverable 2.1 [9], a system service is defined in the OneNet project as the action (generally undertaken by the network operator) which is needed to mitigate a technical scarcity or scarcities that otherwise would undermine network operation and may create stability risks. Even when all network operators face similar system needs, the relevance of different system needs can vary between distribution or transmission networks since these networks serve different purposes. For example, Article 2 in the European Balancing Guideline [10] sets that TSOs are responsible for undertaking actions to “ensure, in a continuous way, the maintenance of system frequency within a predefined stability range […] and compliance with the amount reserves needed concerning the required quality”. Therefore, the needs that arise as a result of the obligation to keep the balancing of the grid, will only be addressed by TSOs. The definition of system service answers the question, “what are the service required to ensure stability of the grid?”. In Deliverable 2.1 of OneNet [9] different definitions that were used in previous H2020 projects of what constitute system services are reported. The review of the previous H2020 project definition together with the experience of the different members of the OneNet team lead to the definition adopted in this report. Therefore, the adopted definition of “system services” extends the definition provided in DIRECTIVE (EU) 2019/944 regarding ancillary services (balancing and non-frequency ancillary services) including also congestion management services [11]. Frequency ancillary service means a service used by a transmission system operator for the active power balancing the power system [11]. Non-frequency ancillary service means a service used by a transmission system operator or distribution system operator for steady state voltage control, fast reactive current injections, inertia for local grid stability, short-circuit current, black start capability and island operation capability [11]. Congestion management service means a service used by a transmission system operator or distribution system operator to avoid or solve grid congestions and bottlenecks that saturate the power transfer capacity of the network [12].

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system operators resort to system services: actions and measures which include, among others, network congestion, voltage control, balancing, rotor angle stability, and system restoration [19]. The system operator can address the need for system services by relying on internal or third-party resources. In the former case, the need for system services is fulfilled by exploiting resources that belong to the system operator. In contrast, in the latter case, the need for system services is addressed involving flexible resources owned by third parties, whose operation is adapted to respond to the signals sent by the relevant system operator to accommodate the power system operation requirements [5]. The system operators can make use of several mechanisms to acquire system services from third parties (e.g., distributed generators, active customers, customers, aggregators). Market and non-market-based mechanisms for acquiring system services include the flexible connection and access agreements, the dynamic network tariffs, the flexibility markets, the bilateral contracts, the cost-based mechanisms, and obligations [20].

Designing an efficient, integrated, and scalable market for the procurement of the system services required by the TSOs and DSOs involves studying the features of all the possible mechanisms and the related implications on the actors involved. In addition, the definition of a theoretical framework for the procurement of system services by third-party resources requires understanding the relevant boundary conditions in the technical, policy, and regulatory terms.

This document aims to contribute to setting the basis for improving the evolution of electricity markets in Europe by reviewing previous works and proposing a theoretical framework for innovative flexibility market designs. This framework is then mapped with OneNet demonstrators' expectations to contribute to the definition of the building blocks for the demos runs and, more importantly, to provide recommendations on the design of the European market.

The structure of the present document is depicted in Figure 1-2. Chapter 1 is the introductive section of the document, the motivation, the goals, and the context of the activities carried out in OneNet Task 3.1 are described. Chapter 2 presents the survey of the main project initiatives concerning the procurement of flexibility from flexibility service providers; common aspects and differences among the various initiatives are studied and discussed. Chapter 3 describes the proposed theoretical market framework useful for modelling and designing mechanisms for procuring flexibility from third-party resources. In chapter 4 the proposed theoretical market framework is applied to the procurement mechanisms of interest for the OneNet demonstrators. Strengths and gaps of the proposed framework as well as the elements that the demonstrators still have to define at this point of the project are discussed. Finally, chapter 5 resumes the findings of the OneNet 3.1 activities by providing closing remarks and recommendations.

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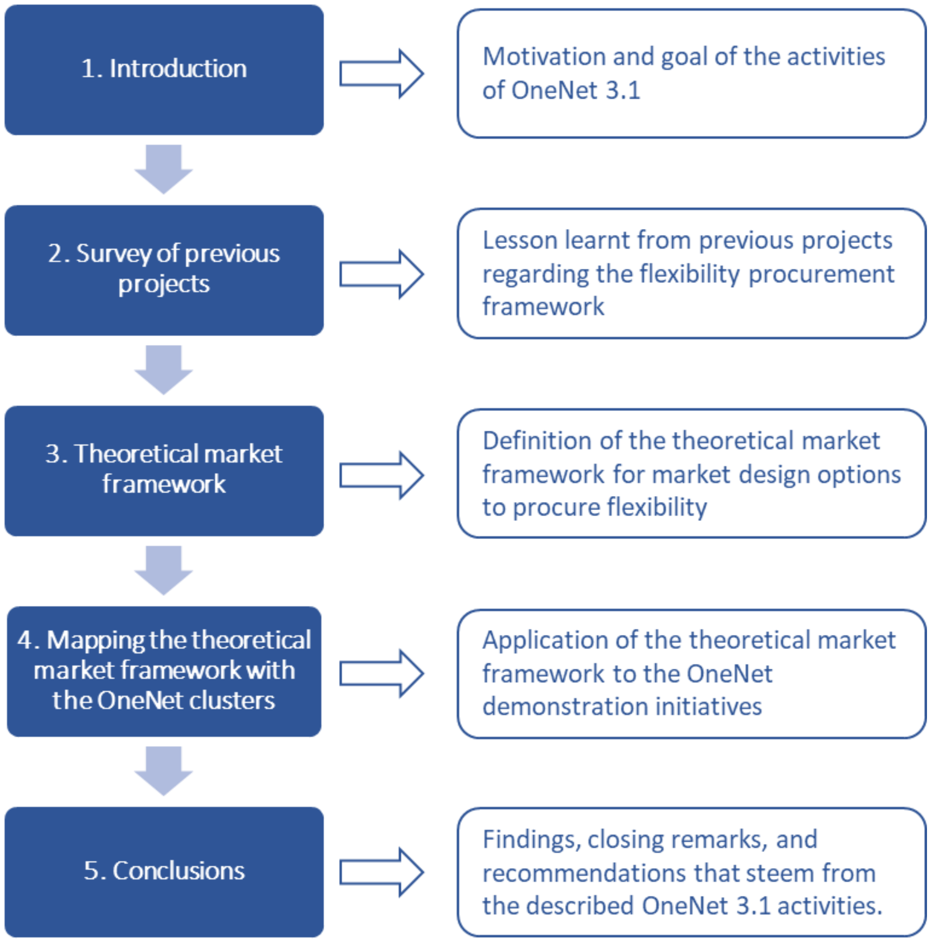

Figure 1-2. Structure of OneNet Deliverable 3.1

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2 Survey of previous projects

Previous European projects have analysed the market design and coordination among market agents. This chapter reviews the existing proposals and studies to build, afterwards, the theoretical framework, which will serve as the basis for the market model framework proposals of OneNet and the related implementation of the demonstrators.

2.1 Goal and methodology of the project survey

Designing an efficient, integrated, and scalable market for the procurement of system services requires taking advantage of the lessons learnt from previous projects on designing the provision of flexibility by third-party assets. This section reviews the use cases in several projects concerning the procurement of flexibility by third-party resources. The project review focuses on the adopted coordination models and market model frameworks. The main objective is to provide a high-level overview of the market model frameworks adopted in the reviewed projects.

The project review is conducted at the use case[3] level [21]; therefore, the first step is to identify the relevant use cases. The relevant information has been collected through a questionnaire (whose template is available in Annex I) that the OneNet project partners have filled out. The project review described in this section applies the definition of submarket proposed in D3.2 of Magnitude: 'a submarket is assumed to be operated by one market operator who is responsible for the market clearing of this specific market according to a specific objective' [22]. Then, according to [23], the market architecture is the 'map of the entire market's component submarkets including the type of each submarket and the linkages between them'. The concept of submarket is described in detail in section 3. The characteristics of the use cases and the aspects of interest for analysing the market model frameworks are the following:

- actors involved,
- number of submarkets,
- the location of submarkets,
- number of buyers,
- types of coordination,
- pricing methods,
- temporal resolution,
- inclusion of grid constraints.

[3] The Use Case describes a system and its functionalities, defining the functional requirements for the business and functional layers as defined in the Smart Grid Architecture Model [21].

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The use case classification and assessment in the project review comprise three primary analyses: a general analysis of the main aspects related to flexibility procurement, its classification according to the CoordiNet market model framework [19], and the analysis of the procurement mechanism dimensions that builds on the CoordiNet market model framework analysis [19]. Figure 2-1 provides an overview of the three stages of the project review analysis.

Figure 2-1. Stages of the use case project review presented in this section

The first stage of the project review analysis depicted in Figure 2-1 aims to provide a general overview of the relevant aspects related to the procurement of system services. The analysis gives information on 1) the coordinated actors, 2) the mechanisms used for procuring flexibility, 3) the buyers of flexibility and the access to DERs, 4) the number of submarkets used in the same architecture for procuring flexibility, and 5) the type of the system needs to cover (i.e. "central" in case of balancing and frequency support, "local" in case of congestion management and voltage support, as defined in [19]). For each of the attributes mentioned above, the quantitative project reviews provide the number of use cases that consider them. The analysis of the number of use cases that address each of these attributes highlights the most investigated options and the gaps in the design and demonstrator of the system services procurement mechanisms.

The CoordiNet project [24], and INTERRFACE [25], [26], are the two previous projects to OneNet which also aim to demonstrate how DSOs and TSOs shall coordinate to procure and activate system services most reliably and efficiently, and define a market model framework to describe the mechanism for procuring system services. The second stage of the project review (Figure 2-1) analyses the relevant use cases according to the CoordiNet market model framework [19]. The CoordiNet market framework was chosen because, among the project reviewed, it considers a larger range of TSO-DSO market models which will constitute the starting point for OneNet. First, the attributes of each use case related to the CoordiNet market model framework are identified; based on this, this use case is assigned the corresponding market model. This analysis aims to categorise the market model framework considered in the reviewed projects and put the basis for the standard framework and terminology to be used for OneNet. Once the market model considered in the reviewed projects are formalised and categorised according to a common framework, the quantitative analysis allows the identification of the most investigated procurement mechanisms and the corresponding gaps of the demonstrator initiatives. Moreover, since actual demonstrator activities within different projects are studied, this analysis also points out

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the gaps of the CoordiNet market model framework; these gaps concern the procurement mechanisms that the CoordiNet framework does not describe.

As anticipated in Figure 2-1, the third stage of the analysis of the reviewed projects focuses on the main aspects of the procurement mechanisms adopted in each of the use cases. This enlarges the description of the TSO-DSO coordination provided by the CoordiNet market model framework. The focus of the analysis here includes other aspects (e.g., submarket type, pricing methods, and temporal resolution) of the flexibility procurement. In addition, this analysis defines groups of homogenous projects to highlight the trends and gaps regarding the market aspects addressed in the already existing project demonstrator works. The outcome of this analysis serves as a basis for identifying and harmonising the market aspects included in the theoretical market framework presented in section 2.6.

2.2 Summary of reviewed H2020 projects

This section briefly describes the projects and commercial initiatives that have been considered relevant to review. These projects have been chosen based on the joint selection with OneNet task 2.1 and the agreement with the partners participating in task 3.1. The project review focuses on identifying the use cases that deal with mechanisms for the procurement of system services from flexible service providers. For the sake of completeness, a brief description of the reviewed projects is provided in Table 2-1. A more detailed description is available in Deliverable 2.1 of the OneNet project [25].

Table 2-1. Description of the reviewed projects

Project	Description
CoordiNet	The CoordiNet Project aims to contribute to the DSOs and TSOs coordination for procuring system services from the same pool of resources [24]. The reliability and effectiveness of the TSO-DSO coordination are tested by implementing large-scale demonstrators that involve consumers and other market participants.
EU-SysFlex	The EU-SysFlex project is focused on the definition of a Pan-European system characterised by the efficient and coordinated use of flexibility to achieve the integration of the largest share of RES [27]. In addition, the EU-SysFlex project defines new services to support the transmission system operation by guaranteeing security and resiliency. The overall objective is to develop a roadmap to support the implementation of cost-effective solutions concerning flexibility [27].
INTERRFACE	The INTERRFACE project (TSO-DSO-Consumer interface architecture to provide innovative system services for an efficient power system) aims to support the coordination between TSOs and DSOs facing common challenges for distributed flexibility procurement [25], [28]. The INTERRFACE project designs, develops, and exploits, an Interoperable pan-European System services Architecture (IEGSA) to act as the interface between power networks (TSO and DSO) and customers seamlessly the coordinated operation of all the stakeholders to procure and use common services.

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NODES	NODES is a commercial initiative focused on the Nord Pool European power exchange, Norway and Germany in particular. The NODES project aims to develop a local flexibility marketplace linked to the existing platforms for intraday and balancing markets [29]. In the NODES platform, the TSO can act as the buyer in the local markets to procure flexibility from the resources connected at the distribution level that have not been selected to cover the flexibility needs of the corresponding DSO. The flexibility procurement in the NODES projects includes two different platforms for availability and activation.
CROSSBOW	The CROSSBOW project proposes the shared use of resources to foster the cross-border management of variable renewable energy sources and storage units. It aims to enable higher penetration of clean energies whilst reducing network operational costs and improving the economic benefits of RES and storage units. Its objective is to demonstrate the contribution to the system flexibility of several different, though complementary, technologies, offering TSOs higher flexibility and robustness. The project aims to achieve better-controlling power exchanges at interconnection points, new storage solutions, and ICT. Furthermore, the project aims to define a transnational wholesale market resulting in fair and sustainable remuneration levels of clean supply technologies through the definition of new business models supporting the participation of new players [25], [30].
TDX-Assist	The objective of the TDX-Assist project is to design and develop novel ICT tools and techniques that would facilitate the development of scalable and secure information systems and the required data exchanges between TSOs and DSOs. The three main novel aspects of the ICT tools and techniques developed in the project are scalability (to deal with new users and increasingly larger volumes of information and data), security (to ensure that the overall system operation is protected from external threats and attacks), and interoperability (information exchanges based on existing and emerging international smart grid ICT standards) [25], [31].
InteGrid	The InteGrid project aims to bridge the gap between the citizens and the technology and solution providers (e.g., utilities, aggregators, manufacturers, and other agents providing energy services). As a result, the InteGrid project aims to enhance active market facilitation and system optimisation services while ensuring sustainability, security, and supply quality [14], [25].
InterFlex	The InterFlex project aim is to demonstrate that combining network automation with the provision of flexibility by local generation and consumption (including sector coupling) can make local energy systems more competitive and more reliable [25], [32]. InterFlex was completed in 2019; the project use cases provided input to five main innovation streams: local flexibility markets, demand response and customer empowerment, smart functions and grid automation, cross energy carrier synergies, and multi-service storage and islanding.
Piclo Flex	The Piclo Flex is a commercial initiative focused on the distribution system level, and it is focused on the United Kingdom. The Piclo Flex project aims to develop a local marketplace for DSO flexibility procurement [33]. More specifically, the Piclo Flex project emphasises the role of the electricity grid in the local procurement of flexibility; the DSO can select the most suitable flexibility provider by considering specific locational, technical, and temporal information.
Enera	The Enera project, linked with EPEX SPOT commercial initiative, was based in Germany, aimed to develop a platform through which the DSO can procure flexibility for solving network congestion [34]. The Enera marketplace concerns a continuous market that includes bid collection, market clearing, technical validation of bids, and settlement.

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FARCROSS	The FARCROSS project aims to connect the main stakeholders of the energy value chain and demonstrate integrated hardware and software solutions that will unlock the use of resources at the regional scale. This may lead to additional cross-border electricity flows, and regional cooperation, and an increase in the efficiency of the use of the transmission grid. Furthermore, it proposes using state-of-the-art digital technologies within the power system to increase and optimise coordination among the TSOs and between the TSOs and the energy producers. Moreover, in the FARCROSS project, a next-generation electricity market is defined and implemented that will operate on a regional basis and will make use of the dispersed assets and take advantage of the increased presence of RES to create economic benefits for the stakeholders [25], [35].
GOPACS	The GOPACS commercial initiative, based in The Netherlands, aims at developing a grid operator platform for congestion management [36]. Specifically, GOPACS develops an architecture that connects several market platforms to enhance the coordination between the different actors involved in the procurement of flexibility. The first application of GOPACS includes intraday congestion management.
SmartNet	The SmartNet project aims to provide optimised instruments and modalities to improve the coordination among the system operators at the national and local levels (respectively, the TSOs and DSOs). This coordination includes the information exchange for the procurement of ancillary services (balancing, voltage control, congestion management) from resources located at the distribution level (flexible load and distributed generation) [25], [37].
SYNERGY	The SYNERGY project introduces a novel reference Big Data architecture and platform that leverages data related to the electricity domain from diverse sources (APIs, historical data, statistics, sensors/ IoT, weather, energy markets and various other open data sources). The aim, in this case, is to help electricity stakeholders to improve their internal intelligence on electricity-related optimisation functions while getting involved in novel data and intelligence sharing (and trading) models. The benefits are obtained by shifting from individual decision-making to a collective intelligence model. To this end, SYNERGY develops a highly effective Big Energy Data Platform and Artificial Intelligence Analytics Marketplace, accompanied by big data-enabled applications for the electricity stakeholders [25], [38].
OSMOSE	The OSMOSE project focuses on achieving the integration of a larger amount of RES generation through the deployment of flexibility. The approach chosen considers the increased need for flexibility, which should reduce the cost involved in keeping the balance between supply and demand in electricity markets, and should be provided by flexibility sources (RES, demand-response, grid and new storages). Furthermore, the OSMOSE approach considers all the system requirements to capture the synergies existing among different solutions, in order to avoid stand-alone solutions that result in a lower overall efficiency [25], [39].
FLEXITRANSTORE	The FLEXITRANSTORE project (An Integrated Platform for Increased FLEXIbility in smart TRANSmission grids with STORage Entities and large penetration of Renewable Energy Sources) aims to contribute to the evolution towards a pan-European transmission network with high flexibility and high transfer capacity. This project also develops a next-generation Flexible Energy Grid (FEG) platform to be integrated into the European Internal Energy Market (IEM). The developed novel smart grid technologies, methods and new market approaches aim to increase the amount of flexibility available and mobilized in the European power system [25], [40].

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PLATONE	The PLATONE project (PLATform for Operation of distribution NEtworks) aims to develop an architecture for testing and implementing a data acquisitions system characterised by a customer access layer and a service layer. The proposed architecture allows authorities to achieve a greater stakeholder involvement and enables efficient and smart network management [25], [41].

Table 2-2 provides an overview of the use cases that have been considered; but not all the listed use cases have been considered relevant for further analysis.

It is worth highlighting that only several use cases of each of the projects have been reviewed. The information on the reviewed use cases has been collected considering a service-based approach (i.e. one use case means one system service). Only the use cases concerning a flexibility procurement mechanism, and the related exchange for solving system services are included. Use cases regarding other aspects (e.g., information exchange, control strategies) are out of the scope of the present survey. Therefore, the project survey in this section provides only a partial representation of every single project. Nevertheless, given a large number of uses case reviewed, it does not hamper the validity of the survey, which provides a comprehensive picture of the main initiatives addressed in Europe regarding the mechanisms for flexibility procurement.

Table 2-2. Overview of the reviewed use cases in OneNet Subtask 3.1

	Project name	**Number of analysed use cases**
1	CoordiNet [24]	12
2	EU-SysFlex [27]	10
3	INTERRFACE [25], [28]	8
4	NODES [29]	4
5	Smartnet [25], [37]	4
6	Crossbow [25], [30]	3
7	TDX-ASSIST [25], [31]	3
8	InteGrid [14], [25]	2
9	InterFLEX [25], [32]	2
10	Piclo Flex [33]	2
11	Enera [34]	1
12	FARCROSS [25], [35]	1
13	GOPACS [36]	1
14	Synergy [25], [38]	1
15	OSMOSE [25], [39]	1
16	Flexitranstore [25], [40]	1
17	PlatOne [25], [41]	1

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2.3 General analysis of the reviewed projects

The general analysis of use cases of the projects mentioned in section 2.2 focuses on several aspects relevant for describing the mechanism used to procure flexibility from the third-party resources. The main elements identified for describing the different procurement frameworks are listed in Table 2-3. Some of the elements included in Table 2-3 apply to the procurement processes of any exchange of goods and services; contrariwise, some elements have a specific meaning related to the specific electric flexibility procurement and provision concerned. All the elements listed in Table 2-3 have been collected from the projects to achieve a meaningful picture of the different procurement mechanisms considered and have played a role in the analysis described in this chapter. The different elements of interest described in Table 2-3 are discussed in more detail in relation to the different projects and initiatives in sections 2.3.1 (coordinated actors), 2.3.2 (the mechanism used for procuring system service), 2.3.3 (buyers of flexibility and direct TSO access to DERs), 2.3.4 (number of submarkets for procuring flexibility), and 2.3.5 (need type).

Table 2-3. Elements of interest for the project review of the exploited procurement mechanisms

Procurement mechanism aspects under review	**Description**
Coordinated actors	The "Coordinated actors" element refers to the actors that interact in the process of procuring flexibility. Coordination is meant with its broad meaning, the action of making all the parties involved in a plan or activity work together in an organised way [42].
Mechanism used for procuring system services	The element "Mechanism used for procuring system service" describes the set of procedures that allow one party to define an agreement to acquire the system service from another party.
Procurement timeframe	The element "Procurement timeframe" identifies how much time in advance the buyer-seller agreement is concluded to the flexibility service delivery. A great variety of procurement timeframes can be designed and observed (from near-to-real-time to year ahead).
Pricing method	The "pricing method" element describes the methodology used to calculate the final price applied to the exchange of the good or service between the buyer and seller. The pricing method adopted depends on the particular procurement mechanism [20].

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Number of submarkets used to procure system services	The element "number of submarkets"[4] describes if the architecture for the flexibility procurement, and then for matching demand and supply, takes places in one or more marketplaces [19]. The element "number of submarkets" defines the number of marketplaces in a defined area. To illustrate, two local submarkets in different sites are not multiple submarkets; conversely, considering a delimited area, a local DSO submarket with an overarching TSO submarket are considered multiple submarkets.
Buyer of flexibility	The "buyer of flexibility" is the role assigned to the actor that buys flexibility [19].
Access to DERs granted to the TSO	The element "Access to DERs granted to the TSO" describes the right granted to the TSO to procure system services from the resources connected to the distribution grid [19]. If the TSO have access to DERs, the TSO can directly interact with DERs in the procurement stage. The activation of the flexibility resources has to involve the relevant DSO; however, this aspect is out of the scope of the project review.
Integration with existing submarkets	The element "Integration with existing submarkets" describes if the flexibility procurement mechanism interacts with, or affects, the already existing electricity submarkets. The outcome of the existing submarkets can represent a baseline upon which to define the needs for flexibility. Moreover, the provision of flexibility may affect the participation of the resources in the already existing submarkets.
Geographical scope of the submarket	The "Geographical scope of the submarket" element intends to capture the size of the flexibility procurement areas [20].
Methodology used to validate the flexibility bids from a technical perspective	The element "Methodology used to validate the flexibility bids from a technical perspective" intends to capture the peculiarity of the electricity exchanges. In fact, unlike other sectors, the electricity exchanges are affected by the physical nature of the grid. The electricity submarkets have to consider the constraints imposed by the electricity grid [20].
Coordination processes	The element "Coordination processes" focuses on the processes for coordinating the actors that have been of primary interest for the reviewed project. The procurement of flexibility, from the need formalisation to the payment transaction, is a complex procedure comprising several processes

[4] D3.2 of Magnitude: 'a submarket is assumed to be operated by one market operator who is responsible for the market clearing of this specific market according to a specific objective' [22]

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	(e.g., resource registration & prequalification, grid assessment, bid collection, submarket clearing, metering, baselining, settlement).
Nature of the need	The element "Nature of the need" describes if the flexibility need can be satisfied at the central level (by all the resources connected to the grid) or at the local level (only by the resources connected in a delimited area of the grid) [19], [43].
System services considered	The "System service considered" element captures the fact that the need for flexibility originates from the need to contribute to achieving a safe operation of the power system. Traditionally, the operation activities of the power system are classified in system services (e.g., frequency control, voltage control, congestion management) [43]. Therefore, the specification of the services on which each of the reviewed use cases is focused is relevant.
Products considered	The element "Products considered" relates to the fact that the provision of a system service involves the exchange of a product between seller and buyer. The products related to the system services can be harmonised and classified according to specific attributes and corresponding values [43]. However, in the most general terms, the products exchanged for satisfying the flexibility needs can be described in terms of the availability and the activation of active and reactive power.

2.3.1 Coordinated actors

The reviewed projects focus on the procurement of flexibility for the power system operation. The exploitation of the flexibility of the connected resources requires some extent of coordination among the actors involved. Therefore, to understand the framework of the coordination models and market model framework introduced in the projects, it is of the utmost interest to identify the coordinated agents and their interactions. As a starting point, the interacting couples are identified. An interaction is defined through the exchange of flexibility (e.g. a provider that sells flexibility or SOs who interact since the flexibility has to pass through networks that are operated by different operators). As previously mentioned, the use cases that are reviewed concern a flexibility procurement mechanism, and the related exchanges for solving system services are included. The information exchange required to accomplish the flexibility provision (from procurement to settlement), are included in the analysis. However, use cases regarding only other aspects (e.g., information exchange, control strategies) are out of the scope of the survey. The analysis is based on the assumption that the interaction includes two parties that form the interacting couple [44]. Therefore, the complex scheme of interactions that compose a market architecture can be fully decomposed in terms of couples of interactions [44]. Figure 2-2 provides quantitative information about the interacting couples considered in the use cases of

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the reviewed projects. This information is relevant for identifying which are the interactions that have been of great interest up to now. Table 2-4 provides detailed information on this; the interacting couples of interests for each reviewed project are highlighted in this table.

In Table 2-4, TSO stands for Transmission System Operator, DSO for Distribution System Operator, system operators defined as the party responsible for operating, ensuring the maintenance of and, if necessary, developing the 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 of the distribution or transmission of electricity [45]. In Table 2-4, IMO stands for an Independent Market Operator defined as an entity, different from the other actors involved in the flexibility procurement, that provides a service whereby the offers to sell electricity are matched with bids to buy electricity, this usually is an energy/power exchange or platform [45]. FSP stands for Flexible Service Provider defined as any entity that offers flexibility services in the market, based on acquired (aggregated) capabilities, usually from third parties [46]. In Figure 2-2, peer-to-peer concerns the interactions between FSP-FSP or among buyers and sellers of electricity without the involvement of third parties.

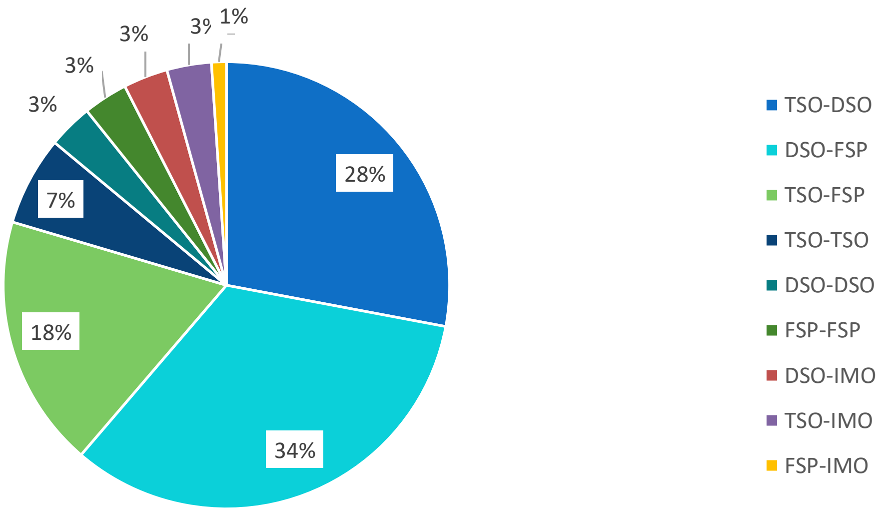

Figure 2-2. Percentage of observed use cases for each coordinated couple

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Table 2-4. Detailed analysis of the interaction couples included in the use cases of the reviewed projects

Project name	**TSO - TSO**	**TSO - DSO**	**DSO - FSP**	**TSO - FSP**	**DSO - DSO**	**Peer-to-peer**	**SO - IMO**	**FSP - IMO**
CoordiNet		X	X	X	X	X		
EU-SysFlex		X	X	X			X	X
INTERRFACE	X	X	X	X		X		
NODES		X	X	X	X		X	X
CROSSBOW	X	X		X			X	
TDX-ASSIST		X	X	X				
InteGrid		X	X					
InterFLEX			X					
Piclo Flex			X	X		X	X	X
Enera				X			X	X
FARCROSS	X			X			X	
GOPACS		X	X	X				
Smartnet		X	X				X	
Synergy			X					
OSMOSE		X		X				
Flexitranstore	X	X	X	X				
PlatOne		X	X			X	X	

Figure 2-2 and Table 2-4 highlight that the majority of the reviewed projects address the chain TSO-DSO-FSP. The remaining interacting couples have attracted less interest within the reviewed projects.

2.3.2 Mechanism used for procuring system services

As already introduced in Table 2-3, several mechanisms can be implemented to acquire system services from third parties (e.g., distributed generators, active customers, consumers, aggregators). Generally speaking, the mechanism for acquiring system services can be classified into market-based (or explicit[5]) and non-market-based (or implicit[6]) mechanisms. Among market-based mechanism for acquiring system services are included flexibility markets and bilateral contracts [20]. While, non-market based mechanisms are flexible connection and access agreements, dynamic network tariffs, cost-based mechanisms, and obligations [20]. Each procurement mechanism can be regulated to a larger or smaller extent depending on the constraints introduced in it by the

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[5] Explicit (or incentive-driven) mechanisms involve the provision of committed, dispatchable, flexibility that can be traded on the different energy markets (wholesale, balancing, congestion management, etc.). Because this type of flexibility is dispatchable, and can be tailored to the markets' exact needs (size and timing), it may offer specific added value for e.g. balancing and capacity management [47], [48], where the system flexibility requirements are determined in advance.

[6] Implicit (or price-based) mechanisms refer to the prosumers' reaction to price signals. As implicit mechanisms reflect the variability on the market and the network, prosumers can adapt their behaviour (through automation or personal choices) to save on energy expenses by shifting their load and/or generation to periods with low/high energy prices, or low grid prices.

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regulation. Table 2-5. describes these main mechanisms, more complex mechanisms can be developed by combining them [20]. As an example, a complex procurement mechanism can result from the combination of local flexibility markets and obligation. The provision of the system services up to a minimum level can be mandatory, as a connection requirement condition; additional service provision capability can be provided voluntarily by the connected resources using a local market mechanism [20].

Table 2-5. Description of the market and non-market-based mechanisms for acquiring system services.

Procurement Mechanism	Description
Obligation	The obligation mechanism represents a non-market solution in which third parties are obliged to provide the system service when required by the system operator and without any remuneration. It is a non-market-based mechanism.
Cost-based	Within a cost-based mechanism, the service providers are remunerated for the actual cost of providing the service. In general, cost-based mechanisms require auditing the providers' costs and defining an adequate margin for providers' return. It is a non-market-based mechanism.
Dynamic network tariffs	The dynamic network tariffs mechanism is characterised by the differentiation of network tariffs on temporal and spatial bases. Consequently, the third parties provide system services by adapting their electric behaviour according to the received price signal. It is a non-market-based mechanism.
Flexible access and connection agreements	The flexible access and connection agreements (or dynamic grid connection agreements) concern the formalisation of an agreement between the system operator and the service provider. Flexible connection means that the power exchange at the network interface can be reduced according to the grid operator's needs. Generally, flexible access and connection agreements are reached for new connections. The flexible access and connection agreements mechanism is a non-market-based mechanism.
Bilateral contract	The bilateral contract mechanism involves achieving a binding agreement between two parties, the TSO or DSO and the service provider. The contract states the agreed terms for the service provision defined during the bilateral negotiation process. Generally, the bilateral contract mechanism is implemented for existing connected resources and constrained situations. The bilateral contract mechanism is a market-based mechanism.
Flexibility market	The flexibility market mechanism concerns the definition of a marketplace dedicated to the exchange of flexibility. Flexibility markets consist of an auction procedure characterised by a tendering process in which the sellers offer their flexibility by submitting bids. The related market can be local or system-wide according to the type of flexibility traded. The flexibility market category, considered for the project survey described in this section, includes both the auction and exchange market mechanism, as defined in section 3.1. Flexibility markets are auction markets characterised by the presence of a unique buyer or few buyers (e.g., TSO, DSO, FSP, any other commercial party) and multiple sellers (e.g., FSPs and any other commercial party). Flexibility markets are exchange markets if exist a centralized market where the bids specify price and quantity or a supply or demand curve and price negotiation is not possible since many buyers and sellers participate; thus, a market operator is involved. The flexibility markets that have been of interest for the reviewed projects have a monopsonistic and weak oligopsonistic structure [25]. In monopsonistic markets, the sellers offer their flexibility to a unique buyer (the TSO or the DSO), while in the weak oligopsonistic markets, the buyers are few (in general, the TSO and DSO, or a system operator and several FSPs) [25]. The flexibility market mechanism is a market-based mechanism.

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Figure 2-3 provides quantitative information about the procurement mechanisms adopted in the use cases of the reviewed projects. This information is relevant for identifying which are the flexibility procurement mechanisms most frequently considered up to now. Moreover, Table 2-6 provides more detailed information about the adopted procurement mechanism for each reviewed project.

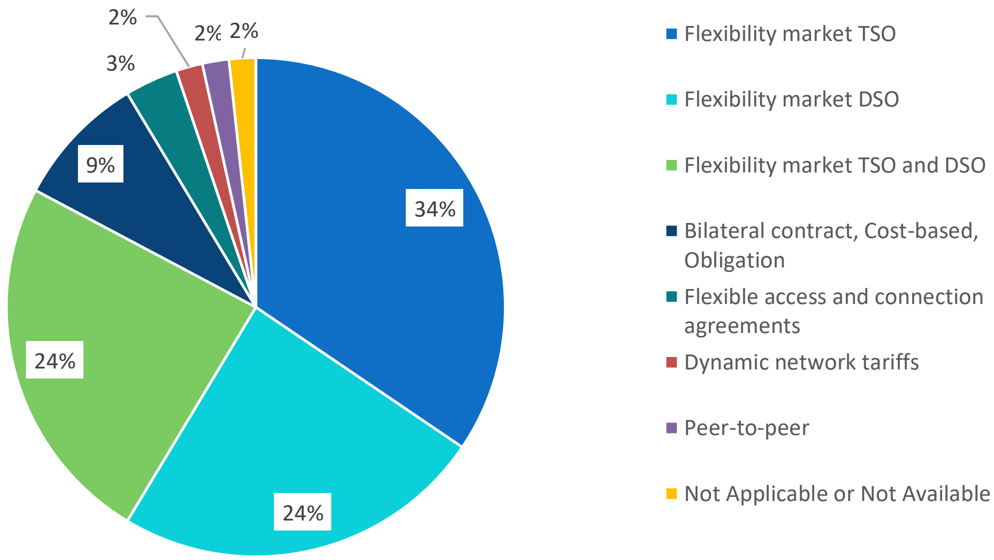

Figure 2-3. Percentage of observed use cases for each mechanism for acquiring system service

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Table 2-6. Detailed analysis of the procurement mechanisms adopted in the use cases of the reviewed projects

Project name	Bilateral contract, Cost-based, Obligation	Dynamic network tariffs	Flexible access and connection agreements	Flexibility market TSO	Flexibility market DSO	Flexibility market TSO and DSO	Peer-to-peer
CoordiNet	X			X	X	X	X
EU-SysFlex			X	X	X	X	
INTERRFACE	X	X		X	X	X	
NODES					X	X	
CROSSBOW	X			X			
TDX-ASSIST				X	X		
InteGrid					X		
InterFLEX					X		
Piclo				X	X		X
Enera				X			
FARCROSS				X			
GOPACS						X	
Smartnet				X	X	X	
Synergy					X		
OSMOSE				X			
Flexitranstore				X			
PlatOne	X	X					

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As highlighted in Figure 2-3 and Table 2-6, the majority of the reviewed use cases focus on flexibility markets in which there is only one buyer (the TSO or the DSO). A significant share of these use cases investigates the functioning of a unique market in which both the TSO and DSOs participate as buyers of flexibility. A minor share of these use cases considers other mechanisms like bilateral contracts, cost-based ones, obligations, and peer-to-peer mechanisms. Few use-cases focus on procurement mechanisms such as network tariffs and connection agreements. Based on these results, the main focus of this document is on flexibility markets, as the main mechanism analysed in previous projects.

2.3.3 Buyers of flexibility and direct TSO access to DERs

As shown in Table 2-3, the buyer of flexibility is the role that any of the actors involved (e.g., system operators, FSPs, aggregators) in flexibility procurement can play. The buyer of flexibility is the entity that acquires the flexibility service from the flexibility service provider in charge of operating the flexible resources [19]. Thus, the flexibility procurement architecture strongly depends on the actor who plays a buyer role, the number of buyers, and the power system level at which the flexible resources are connected. Typically, the buyer's role is played by the TSO or the DSO, requiring flexibility for operating the corresponding grid. Since the constraints introduced by the grid in the flexibility service provision can significantly affect the provision of this service, it is of interest to highlight the cases in which the TSO directly accesses the resources connected at the distribution system level. In addition to the TSO-FSP coordination, this scenario requires defining the coordination between the TSO and the corresponding DSO.

Figure 2-4 provides an overview of the reviewed use cases classified according to the identity of the flexibility buyer and the corresponding direct access to DERs granted to the TSO. In Figure 2-4 the option TSO and DSO does not fully correspond with the common market model, other mechanisms are included (e.g. the fragmented market model), as defined in [43]. In Figure 2-4, the inner circles describe the identity of the flexibility buyer for the reviewed use cases, the outer circle quantifies the corresponding use cases in which direct access to DERs is granted to the TSO.

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Figure 2-4. Percentage of observed use cases classified according to the buyer's identity and the corresponding access to DERs granted to the TSO

Figure 2-4 points out that in the vast majority of the reviewed use cases, TSO, DSO, or both are the buyers in the flexibility procurement mechanism. Considering the use cases in which the TSO is involved as a single buyer or in competition with the DSO, the use cases that consider the TSO access to DERs are the majority. Only few use cases concern a procurement mechanism that involves peers as buyers of flexibility.

2.3.4 Number of submarkets for procuring flexibility

The number of submarkets used for procuring flexibility is a fundamental aspect of the architecture of the market model. The main distinction is between single and multiple submarkets procurement architectures [19]. As introduced in Table 2-3, "number of submarkets" describes the number of marketplaces for procuring flexibility in a submarket area. For example, a local DSO submarket with an overarching TSO submarket represents a multiple market architecture. In contrast, two local submarkets corresponding to two independent procurement areas, even if they are two different submarkets, they change only in location but can have the

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same market architecture. The relevance of the "number of submarkets" lies in the fact that it shapes the procurement architecture and influences the coordination among the actors. Figure 2-5 and Table 2-7 provide a quantitative overview of the "number of submarkets" concerning the use cases of the reviewed projects. It is important to distinguish between the architectures featuring a single submarket and those featuring multiple submarkets [19].

Figure 2-5 and Table 2-7 highlight the fact that the reviewed use cases are roughly split in half between the multiple and the single submarket architectures. Still, most of the use cases (a bit more than half) consider a single submarket architecture, as highlighted in section 2.3.5; this result is related to the fact that most use cases focus on local needs.

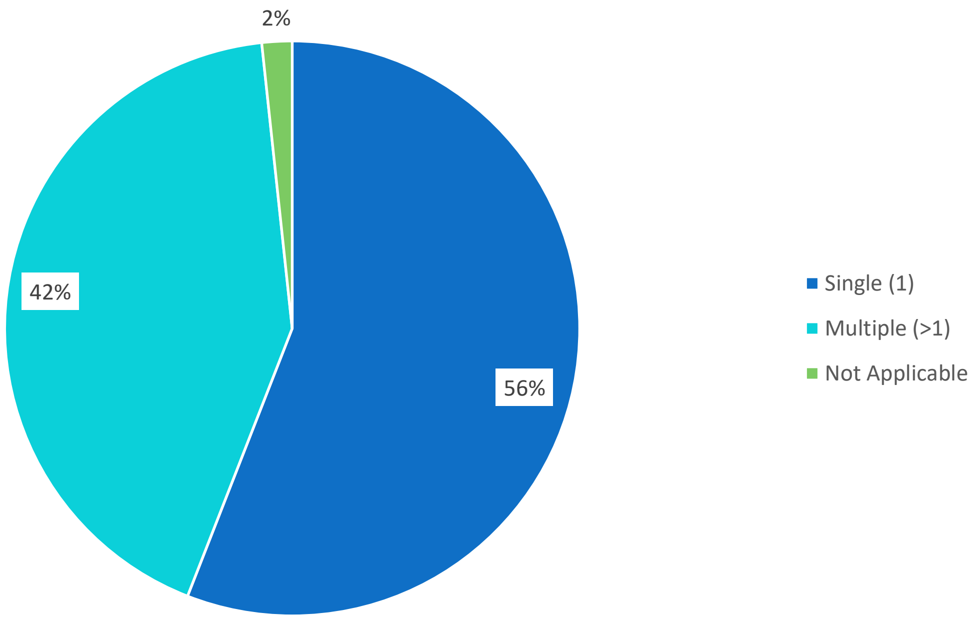

Figure 2-5. Overview of the number of submarkets used for procuring flexibility in the use cases of the reviewed projects

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Table 2-7. Number of submarkets used for procuring flexibility in the use cases of the reviewed projects

	Single (1)	Multiple (>1)
CoordiNet	X	X
EU-SysFlex	X	X
INTERRFACE	X	X
NODES	X	X
CROSSBOW	X	
TDX-ASSIST	X	X
InteGrid	X	X
InterFLEX	X	
Piclo	X	
Enera	X	
FARCROSS	X	
GOPACS	X	
Smartnet	X	X
Synergy	X	
OSMOSE	X	
Flexitranstore	X	
PlatOne	NA	NA

2.3.5 The need types

The attribute "need type" influences the procurement mechanism design, since it determines the size of the procurement area. As described in Table 2-3, the "type of the need" can be 'central', if the need for system services can be satisfied by all the resources connected to the power system, as the case for the resources that contribute in frequency control; or 'local' if the need for flexibility can only be satisfied by the resources in the corresponding area, as it happens for congestion management and voltage control , [19], [20]. A procurement mechanism can be appropriate for only one type of need (nature of the need) or appropriate for both of them. In the latter case, the flexibility product that is procured can satisfy both types of needs. The market mechanism is, in the latter case, service agnostic. The service provider could be unaware of the use of the flexibility provided, since the procurement mechanism is not linked to a specific service.

Figure 2-6 and Table 2-8 provide a quantitative overview of the "nature of the need" concerning the use cases of the reviewed projects.

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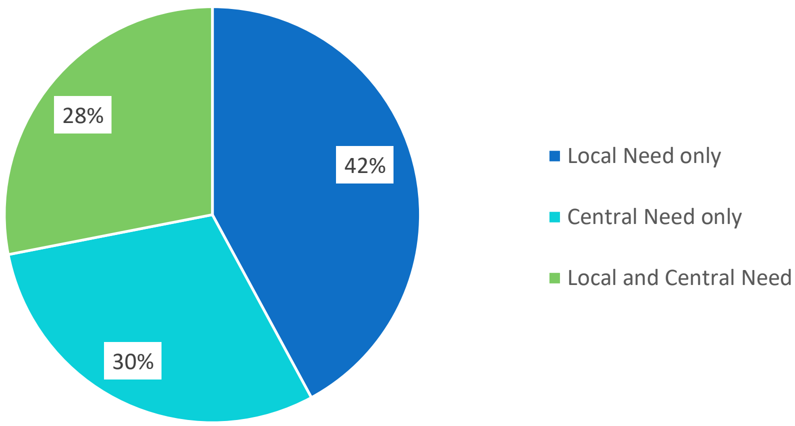

Figure 2-6. Overview of the need type covered in the use cases of the reviewed projects

Table 2-8. Type of the need covered in the use cases of the reviewed projects

	Local Need only	**Central Need only**	**Local and Central Need**
CoordiNet	X	X	X
EU-SysFlex	X	X	X
INTERRFACE	X	X	X
NODES	X		X
CROSSBOW		X	
TDX-ASSIST	X	X	X
InteGrid	X		X
InterFLEX	X		
Piclo	X	X	
Enera	X		
FARCROSS		X	
GOPACS			X
Smartnet		X	X
Synergy	X		
OSMOSE		X	
Flexitranstore		X	
PlatOne	X		

Figure 2-6 and Table 2-8 highlight the fact that the majority of the use cases focus on procuring flexibility to cover a local need, either in a stand-alone fashion or in combination with a central need. However, the quantitative results highlight that all the three possible options for “nature of the need” are adequately represented in the reviewed projects.

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2.4 Classification according to the CoordiNet market model framework

2.4.1 The CoordiNet market model framework

The analysis of the market architecture of the reviewed projects described in this section makes use of the market model framework proposed in the CoordiNet project. In the CoordiNet project, several architectures are designed and tested for the coordinated TSO-DSO procurement of flexibility provided by the FSPs. The models considered in the CoordiNet Project are [19]:

i. Local Market Model;
ii. Central Market Model;
iii. Common Market Model;
iv. Integrated Market Model;
v. Multi-level Market Model;
vi. Fragmented Market Model;
vii. Distributed Market Model.

Each market model comprises four building blocks whose configuration can be represented in a decision tree characterizing this market model framework. Table 2-9 describes these four building blocks [19].

Table 2-9. Description of the building blocks that comprise the market model framework proposed in the CoordiNet project. Source [19].

Block	Attribute	Description
Need	Central; Local	The system operator need that will be addressed
Buyer	TSO; DSO; Peers; Commercial party	The stakeholders that will buy the flexibility service to solve the need
Submarkets	Single (1); Multiple (≥1)	The number of submarkets that are considered for the flexibility procurement
Resources	Yes; No	If the TSO has access to the DERs

As shown in Table 2-9, the need for flexibility could be central or local [19]. A central need exists when the need is at the overall system level. Then, all resources connected to a specific control area can satisfy the need; even all those resources in the interconnected system could satisfy a need if the required coordination schemes exist among control areas. Frequency control is an example of a central need. On the contrary, a local need exists when the service providers must be located within a specific area. Therefore, only the resources belonging to a specific region of the control area can satisfy the need concerned. Voltage control and network congestion management are local needs.

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As pointed out in Table 2-9, several stakeholders (TSO, DSO, MO, FSP, BRPs[7], and active and passive network customers, among others) could participate in the procurement of flexibility, buying the flexibility required to cover the need concerned. The buyers considered in CoordiNet project are the TSO, DSO, peers, and other commercial parties [19].

Table 2-9 highlights the number of blocks characterising the market model and describes the market model that corresponds to the different combination of blocks [19]. The single market model is used in the cases where one marketplace is used to cover a particular need or multiple needs; all the stakeholders interested in receiving or providing the flexibility service have to participate in that submarket. Multiple submarkets exist when more than one marketplace, each with different actors, is used to cover a particular need. A centralised market for frequency control represents a single submarket. Alternatively, an architecture comprising several local submarkets for voltage control and a centralised submarket for frequency control is considered a multiple markets framework.

The access to DERs (generation, consumption, and storage connected at the distribution level) characterises the market model by defining the capability of the TSO to procure system services making use of the resources connected at the distribution level [19]. Although access to DERs can be granted or not to the TSO, in the former case, TSO-DSO coordination is required to prevent any issue in the distribution network.

Table 2-10 reports on the coordination schemes considered within the CoordiNet project and the structure of each scheme in terms of the four building blocks mentioned in Table 2-9. The DSO has access to DERs in all market models in Table 2-10.

Table 2-10. Structure of the coordination schemes considered within the CoordiNet project. Source [19]

Need	Buyer	Submarkets	TSO access DERs	Market model
Local	DSO	1	No	Local
Central	TSO	1	Yes	Central
Central	TSO	1	No	Central
Local and Central	DSO and TSO	1	Yes	Common
Local and Central	SO and commercial party	1	Yes	Integrated
Local and Central	DSO and TSO	≥1	Yes	Multi-level
Local and Central	DSO and TSO	≥1	No	Fragmented
Local	Peers	≥1	No	Distributed
Local and Central	Peers	≥1	No	Distributed

[7] BRP stands for Balancing Responsible Party. BRP represent a particular class of FSP that contributes to the system operation only by participating in the active power balancing of the power system. Adapted from Production Responsible Party available in [45].

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The local market model describes the cases in which a single local submarket is considered, and it is not explicitly coordinated with other submarkets (e.g. a central submarket) [19]. A local submarket covers a local need; the buyer is the DSO; the number of marketplaces is one; and the TSO has no access to DERs. The local submarkets are designed to cover local needs, and they involve no market-based coordination between the TSO and the DSO.

The central market model concerns the procurement of flexibility services for covering central needs [19]. In this model, the TSO is the single buyer of flexibility and may have or not access to DERs. In the first case, the DSO is not actively involved in the market-based procurement of flexibility. The potential problems in the distribution network caused by the activation of DERs are addressed through a technical coordination scheme. In the latter case, the TSO is allowed to procure flexibility provided only by the resources belonging to its control area of the transmission system; therefore, no coordination with the DSOs is required.

The common market model is designed as a single submarket for addressing both the central and the local flexibility needs; both the TSO and the DSO are involved in this market model as buyers, and they share the same set of resources [19]. The common market model addresses the local and the central needs; the buyers are both the TSO and the DSO; the number of submarkets is one; and the DSO and the TSO has access to DERs. Since local needs are addressed in a unique common submarket, the bids have to include locational information.

The integrated market model extends the concept of the common market model by including flexibility buyers, commercial parties, and TSOs and DSOs [19]. The integrated market model architecture requires an independent market operator to rule the market. The integrated market model is designed for solving local and central needs; the buyers are the TSO, the DSOs, and other commercial parties; the number of submarkets considered in them is one, and the TSO has access to DERs.

The multi-level market model addresses central and local needs by combining several central and local submarkets [19]. In the multi-level market model, the DERs can participate in both the local and central submarkets competing for the resources connected at the transmission level. The multi-level market model is designed for solving local and central needs; the buyers are the TSO and the DSO; the number of submarkets is more than one; and the TSO has access to DERs.

The fragmented market model comprises an independent central submarket and local submarkets; TSOs and DSOs do not compete for procuring flexibility in the same submarket [19]. The main difference concerning the multi-level market model is that no access to DERs is granted to the TSO; therefore, DERs can participate only in local submarkets. The fragmented market model is designed for solving local and central needs; the buyers are TSO and DSO; the number of submarkets is more than one; and the TSO does not have access to DERs.

The distributed market model is designed to represent peer-to-peer exchanges agreed through direct negotiations [19]. The distributed market model is designed for solving local needs and the combination of local

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and central needs; the buyers are only the peers; the number of submarkets is more than one; and the TSO does not have access to DERs.

2.4.2 Project analysis according to the CoordiNet market model framework

The second phase of the project review analysis concerns assessing the corresponding frameworks according to the market model proposed in CoordiNet [19]. For each of the surveyed use cases, the four building blocks described in section 2.4.1 have been considered. The outcome of this analysis, described in Table 2-11, allows assigning to each use case the corresponding CoordiNet market model. Not all the use cases of the reviewed projects fit the CoordiNet market model framework. In some cases, even with some differences in the blocks' attributes, the resulting market model can be somehow framed as a CoordiNet market model. In this case, the resulting market model is referred to in Table 2-11 as a "-like" model. On the contrary, when a straightforward correspondence with the CoordiNet market models cannot be identified, the resulting market model is classified as an "Other". If the use case does not consider a market-based mechanism, it is not possible to assign a market model to it; therefore, the corresponding cell is filled out with "Not Applicable". Furthermore, Figure 2-7 summarises graphically the outcome of the analysis that attempts to describe the use cases of the reviewed projects according to the CoordiNet market model framework associated with it.

Table 2-11. Classification of the use cases of the reviewed projects according to the CoordiNet market model framework

Projects (number of use cases)	Need Type	Buyer	Number of submarkets	TSO Access to DERs	Use cases identified	CoordiNet market model
CoordiNet (2); InteGrid (1); InterFlex (2); NODES (3); SYNERGY (1) EU-SysFlex (1); Piclo (1)	Local	DSO	1	No	11	Local
CoordiNet (1); Crossbow (1); EU-SysFlex (2); FARCROSS (1) TDX-ASSIST (1) Flexitranstore (1) Smartnet (1)	Central	TSO	1	Yes	9	Central
CoordiNet (2); GOPACS (1); INTERRFACE (1); NODES (1)	Central and Local	TSO & DSO	1	Yes	6	Common

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Smartnet (1)						
CoordiNet (4); EU-SysFlex (2); InteGrid (1) TDX-ASSIST (1) Smartnet (1)	Central and Local	TSO & DSO	≥1	Yes	9	Multi-level
CoordiNet (2); Smartnet (1)	Central and Local	TSO & DSO	≥1	No	3	Fragmented
Crossbow (1); INTERRFACE (1)	Central	TSO	1	No	2	Central
Flexitranstore (1)	Central and Local	TSO, DSO, External Stakeholders	1	yes	1	Integrated
CoordiNet (1)	Local	Peers	≥1	No	1	Distributed
INTERRFACE (1)	Local	DSO & Peers	1	No	1	Distributed
INTERRFACE (2)	Local	TSO & DSO	≥1	Yes	2	Other local with multiple buyers
TDX-ASSIST (1)	Central and Local	TSO	≥1	Yes	1	Other central and local
INTERRFACE (1)	Local	TSO & DSO	≥1	No	1	Other local with multiple buyers
EU-SysFlex (1) Enera (1);	Local	TSO	1	Yes	1	Other local
EU-SysFlex (1)	Local	TSO & DSO	1	Yes	1	Other local with multiple buyers
Crossbow (1)	Central	TSO & DSO	1	Yes	1	Other central with multiple buyers
OSMOSE (1)	Central	TSO & Peers	1	Yes	1	Other central with multiple buyers
Piclo (1)	Central	Peers	1	Yes	1	Other central
EU-SysFlex (2)	Central	TSO	≥1	Yes	2	Other central
EU-SysFlex (1); INTERRFACE (1)	Local	DSO	1	Yes	2	Other local
INTERRFACE (1)	Local	DSO	≥1	Yes	1	Other local
PLATONE (1)	Local	NA	NA	NA	1	Not Applicable

Table 2-11 shows that the CoordiNet market model framework is effective in describing the use cases of the reviewed projects. In particular, the majority (71%) of the reviewed use cases include a market model that can be characterised by the set explicitly defined in the CoordiNet Project. A small subset of the reviewed use cases

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concerns a market model that does not correspond to one of the market models defined in the CoordiNet framework. As depicted in Figure 2-7, the reviewed use cases show as prevalent market models the local, central, multi-level, and common market models. These market models correspond to 61% of the reviewed use cases. The fragmented, distributed, and integrated market models describe only 10% of the reviewed use cases. The remaining use cases cannot be fully represented according to the CoordiNet market model framework (Table 2-10). Some of the uses cases that fall in these classes do not define market-based coordination between the buyers, even if the system operator can procure flexibility from the same set of FSPs. However, the procurement mechanism considered in those use cases can be studied and classified through the four market model building blocks described in Table 2-9.

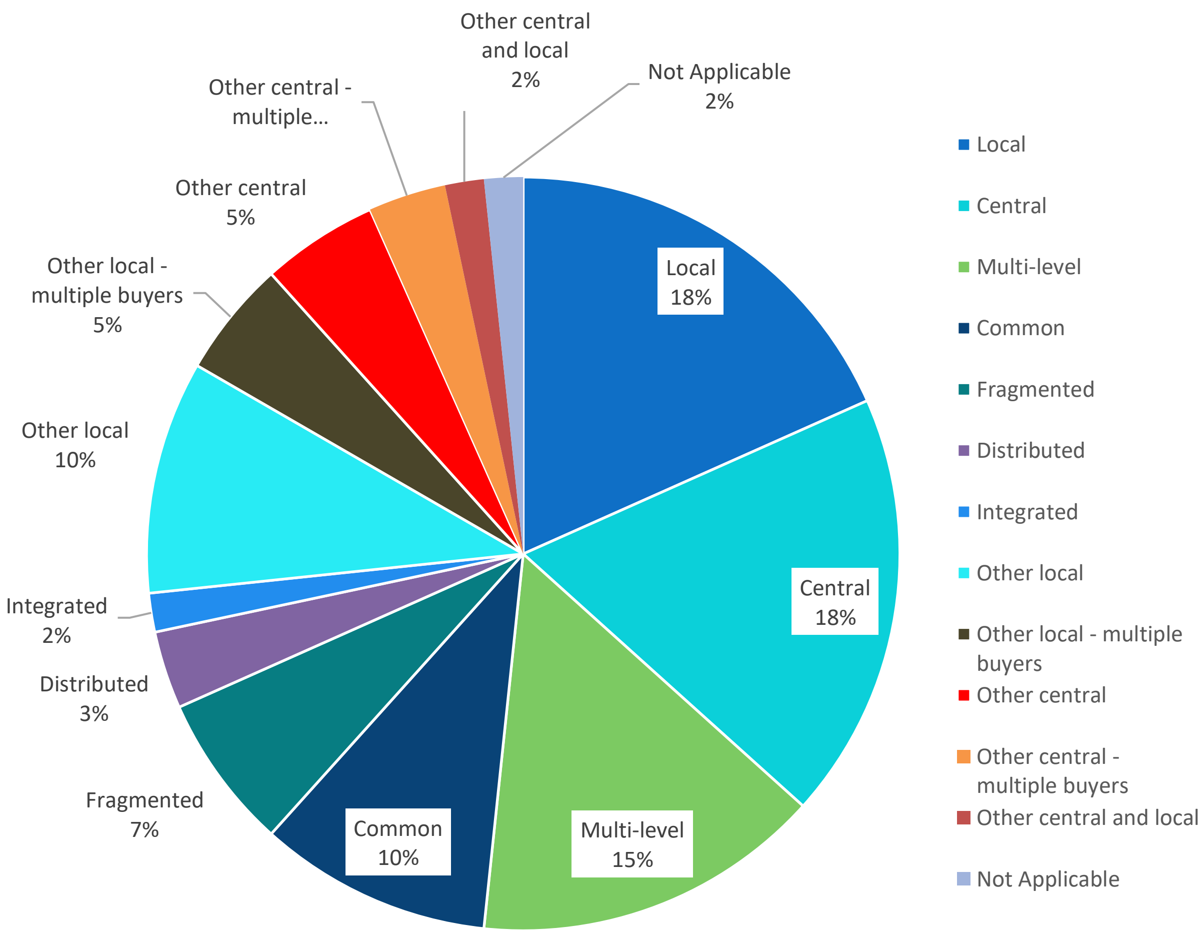

Figure 2-7. Distribution of the use cases of the reviewed project according to the CoordiNet market model framework

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2.5 Analysis of the flexibility procurement process

This section focuses on analysing the procurement process implemented in the reviewed projects (described in section 2.2). The analysis of the procurement mechanism provides relevant information for the assessment of models according to the theoretical market framework presented in section 3. The aspects of interest for analysing the procurement mechanism used in the reviewed projects are described in Table 2-12. Each aspect is defined in terms of possible options and a description that clarifies the corresponding scope.

Table 2-12. Description of the building blocks for the analysis of the procurement practices in the reviewed projects

Aspect	Option	Description
Coordinated actors	1. TSO 2. DSO 3. FSP 4. IMO 5. Others	The block "Coordinated actors" aims to describe the actors that take part in system service procurement.
System service	1. Frequency control (balancing) 2. Voltage control 3. Rotor angle stability 4. Network congestion management 5. System restoration 6. System adequacy 7. Islanded operations	The block "Service" describes the specific grid operation need that pushes the procurement of flexibility. Even if the flexibility provision can be framed to provide more than one system service, the reviewed project use cases mainly focus on one system service.
Procurement mechanism	1. Flexibility markets TSO 2. Flexibility markets DSO 3. Flexibility Market TSO and DSO 4. FSP-to-FSP negotiations (Peer-to-peer) 5. Bilateral contracts (between TSO or DSO and an FSP) 6. Regulated mechanism 7. Flexible connection and access agreement 8. Dynamic distribution tariffs	The "Procurement mechanism" block classifies the procurement practices employed for establishing the agreement between the buyer and the seller of the flexibility services [20]. The attributes of the *Procurement mechanism* block include the classification of the mechanisms into market-based solutions (options from 1 to 5) and non-market based, or regulated, solutions (options from 6 to 8).

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Aspect	Option	Description
Number of submarkets	1. Single (1) 2. Multiple (>1)	As pointed out in the section 'Elements of interest for the project review of the exploited procurement mechanisms, Table 2-3, the "Number of submarkets" is fundamental to characterize the whole architecture used for procuring flexibility. Combining the information drawn from the "Service" and the "Procurement mechanism" makes the main contribution to the description of the procurement process.
Pricing method	1. Pay as bid 2. Pay as cleared 3. Cost-based 4. Regulated tariffs 5. Fixed prices 6. No remuneration	The "*Pricing method"* block describes the methodology used for calculating the final price of the flexibility service provided, according to the definition in Table 2-3. The price as bid method is typically used in discriminatory price auctions, while the pay as cleared method is used for uniform price auctions [20]. Other pricing methods (e.g., cost-based, regulated tariffs, fixed prices) are possible if the procurement process does not involve conducting an auction.

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Aspect	Option	Description
Procurement timeframe	1. Near-to-real-time (15 minutes) 2. Intraday 3. Day-ahead 4. Week-ahead 5. Month-ahead 6. Seasonally 7. Annually	The "*Procurement timeframe*" block defines the timing affecting the provision of the service by the seller, as defined in Table 2-3. The procurement timeframe is classified in the present project review into short-term (options from 1 to 3) and long-term (options from 4 to 7) cases.
Grid assessment	1. Inclusion in the OPF 2. Simplified flow-based criteria 3. Empirical criteria	In the electricity sector, the market outcome is influenced by the status of the grid that links buyers and sellers [20]. The "grid assessment" concerns the inclusion of grid constraints in the procurement of flexibility services; it describes the activity of grid check for selecting or activating the eligible flexibility service providers. Several methods can be used according to the observability of the grid status and the available time for computing the grid calculation.

The use cases of the reviewed projects are analysed for identifying their characteristics according to the aspects described in Table 2-9. Since there are various possible options for the different aspects making a meaningful picture of the reviewed projects, the clustering procedure is based on a high-level classification of each aspect. Table 2-13 summarises the aspects and the corresponding options used for clustering the use cases of the reviewed projects. The coordinated actors and the grid assessment aspects have been neglected in the final analysis.

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Table 2-13. Aspects and options for clustering the reviewed use cases considering the flexibility procurement mechanism

Aspects	Options
Service	1. Network congestion management 2. Voltage control 3. Frequency control 4. Islanded operation 5. Voltage control & Network congestion management 6. Frequency control & Network congestion management 7. System adequacy 8. Other
Procurement mechanism	1. Flexibility Market TSO and DSO 2. Flexibility Markets TSO 3. Flexibility Markets DSO 4. Peer-to-Peer 5. Other mechanisms (e.g., bilateral contracts, regulated)
The number of submarkets	1. Single (1) 2. Multiple (>1)
Pricing method	3. Pay as bid 4. Pay as cleared 5. Pay as bid or pay as cleared 6. Other
Procurement timeframe	a. Long-term (from Annually to weekly) b. Short-term (from Near-to-Real-Time to day-ahead)
Grid assessment	1. Yes 2. No

The reviewed use cases are clustered according to the aspects and the corresponding options described in Table 2-13. The outcome of the cluster analysis is available in Table 2-14. For the sake of clarity, "grid assessment" has been excluded from the assessment of the use cases; otherwise, given the number of aspects and the variety of options, the cluster analysis would lead to an outcome overly fragmented (i.e. a final partition composed of a high number of clusters which contain few use cases, possibly only one). It includes post-

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processing information added to the outcome of the clustering algorithm. The additional information is motivated by clarifying the entries characterised by the "*other*" attribute.

As shown in Table 2-14, the cluster analysis of the reviewed use cases leads to many clusters since the great number of features considered. Even simplifying the clustering by utilising the aggregated attributes values proposed in Table 2-13, the great variety leads to the impossibility of solving the combinatorial problem of identifying only a few homogenous groups of use cases. This outcome highlights the great variety of procurement mechanisms that can be defined, developed, and tested in the reviewed projects. This result provides a measure of the maturity of the field of flexibility procurement mechanisms. Table 2-14 highlights the alignment existing among the use cases of the CoordiNet and the INTERRFACE projects. The most crowded cluster is comprised only by use cases belonging to these two projects. The corresponding procurement process comprises multiple short-term flexibility markets for the TSO and the DSO in which the pricing method involves computing the price as cleared. The goal of this flexibility market is to solve network congestion. The next cluster contains use cases from the GOPACS, InterFLEX, and INTERRFACE projects that define a procurement framework characterised by a single local short-term market to solve network congestion at the DSO level. The third cluster also deals with local needs; it includes use cases that do not consider a flexibility market. The fourth cluster comprises three use cases from CoordiNet, FARCROSS, and InteGrid that address frequency control (a central need), procuring flexibility using a single short-term market in which the TSO is the only buyer, and the FSPs are remunerated according to the market-clearing price.

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Table 2-14. Analysis of the reviewed projects considering the aspects and options defined in Table 2-13

Projects (number of use cases)	Service	Procurement mechanism	Number of submarkets	Pricing method	Procurement timeframe	Number of use cases
CoordiNet (2); INTERRFACE (3)	Network congestion management	Flexibility Market TSO and DSO	>1	Pay as cleared	Short-Term	5
GOPACS (1); InterFLEX (2); INTERRFACE (1);	Network congestion management	Flexibility Markets DSO	1	Other methods	Short-Term	4
Crossbow (1); EU-SysFlex (2); InteGrid (1)	Voltage control & Network congestion management	Other mechanism	1	Other methods	Short-Term	4
CoordiNet (1); FARCROSS (1); INTERRFACE (1) Smartnet (1)[8]	Frequency control	Flexibility Markets TSO	1	Pay as cleared	Short-Term	4
NODES (1) Smartnet (2)[5]	Other (Service agnostic approach)	Flexibility Market TSO and DSO	1	Pay as bid or Pay as cleared	Short and Long Term	3
CoordiNet (1); INTERRFACE (1)	Network congestion management	Flexibility Markets DSO	1	Pay as cleared	Short-Term	2
CoordiNet (2)	Voltage control	Flexibility Market TSO and DSO	>1	Pay as cleared	Short-Term	2
EU-SysFlex (1) Smartnet (2)[5]	Frequency control & Network congestion management	Flexibility Market TSO and DSO	>1	Pay as bid or Pay as cleared	Short-Term	2
OSMOSE (1)	Frequency control	Flexibility Markets TSO	1	Pay as bid	Short-Term	1
TDX-ASSIST (1)	Frequency control and voltage control	Flexibility Markets TSO	1	Pay as bid	Short-Term	1

[8] Smartnet have not defined pricing method and procurement timeframe

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SYNERGY (1)	Frequency control	Flexibility Markets DSO	1	Not Available	Short-Term	1
EU-SysFlex (1)	Frequency control	Flexibility Markets TSO	>1	Pay as cleared	Short and Long Term	1
EU-SysFlex (1)	Frequency control	Flexibility Markets TSO	>1	Pay as cleared	Short-Term	1
Crossbow (1)	Frequency control	Flexibility Markets TSO	1	Pay as bid or Pay as cleared	Short-Term	1
CoordiNet (1)	Frequency control	Flexibility Market TSO and DSO	>1	Pay as cleared	Short-Term and Long-Term	1
Smartnet (1)	Frequency control	Other (multiple options)	>1	Pay as cleared	Short-Term	1
EU-SysFlex (1)	Frequency control & Network congestion management	Flexibility Markets TSO	1	Pay as cleared	Short-Term	1
CoordiNet (1)	Islanded operation	Other mechanism	1	Pay as bid	Short and Long Term	1
PicloFlex (1)	Network congestion management	Flexibility Markets DSO	1	Pay as bid	Long-Term	1
NODES (1)	Network congestion management	Flexibility Markets DSO	1	Pay as bid or Pay as cleared	Short and Long Term	1
CoordiNet (1)	Network congestion management	Flexibility Markets DSO	>1	Pay as bid	Short-Term and Long Term	1
Enera (1)	Network congestion management	Flexibility Markets TSO	1	Pay as bid	Short-Term	1
CoordiNet (1)	Network congestion management	Flexibility Market TSO and DSO	1	Pay as bid	Short-Term	1
INTERRFACE (1)	Network congestion management	Flexibility Market TSO and DSO	1	Pay as cleared	Short-Term	1
INTERRFACE (1)	Network congestion management	Other mechanism	>1	Pay as cleared	Short-Term	1

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TDX-ASSIST (1)	Network congestion management	Flexibility Market TSO and DSO	>1	Other	Short-Term	1
Flexistranstore (1)	Network congestion management	Flexibility Market TSO and DSO	1	Pay as bid or Pay as cleared	Short-Term	1
CoordiNet (1)	Network congestion management	Peer-to-Peer	>1	Pay as bid	Short and Long Term	1
NODES (1)	Other (Service agnostic approach)	Flexibility Markets DSO	1	Pay as bid	Short and Long Term	1
PicloFlex (1)	Other (Balancing)	Flexibility Markets TSO	1	Pay as bid	Long-Term	1
EU-SysFlex (1)	Other (Service agnostic approach)	Flexibility Market TSO and DSO	>1	Pay as cleared	Other (Timeframe agnostic approach)	1
Flexistranstore (1)	Frequency control	Flexibility Market TSO	1	Not Available	Short-Term	1
PLATONE (1)	Other (Voltage control and Rotor Angle Stability)	Other mechanism	NA	Other mechanism	Short and Long Term	1
NODES (1)	System adequacy	Flexibility Markets DSO	1	Not Available	Short and Long Term	1
InteGrid (1)	Voltage control	Flexibility Markets DSO	>1	Pay as cleared	Short and Long Term	1
EU-SysFlex (1)	Voltage control	Flexibility Markets DSO	1	Pay as bid or Pay as cleared	Short and Long Term	1
CoordiNet (1)	Voltage control	Flexibility Market TSO and DSO	1	Pay as cleared	Short-Term	1
Crossbow (1)	Voltage control	Other mechanism	1	Other mechanism	Short-Term	1
EU-SysFlex (1)	Voltage control & Network congestion management	Flexibility Markets TSO	1	Pay as cleared	Short-Term	1
EU-SysFlex (1)	Voltage control & Network congestion management	Flexibility Markets TSO	1	Other mechanism	Short-Term	1

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TDX-ASSIST (1)	Voltage control & Network congestion management	Flexibility Market TSO and DSO	>1	Not Available	Short-Term	1

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2.6 Lesson learnt from the reviewed projects

The project review presented in this section aims to contribute to the OneNet objective of aligning the concepts related to market design, regulation, demonstrators, and the definition of the theoretical market framework for innovative flexibility procurement market design. The described project review offers an overview of the flexibility procurement processes and the coordination practices which are developed, adopted, and tested in previous projects. The project review presented in this section focuses on the coordination models and the market models to identify similarities and differences among the previous projects and highlight trends and gaps in the current status of flexibility procurement process formalisation.

The first point highlighted by the project review is the existing large variety of market models that have been proposed, adopted, and tested for flexibility procurement. Even if the main trends are related to market-based procurement processes that involve the coordination of TSO and DSOs, a non-negligible part of the projects focuses on other mechanisms and actors. It supports the idea that there is no unique way to procure flexibility and reflects the fact that the boundary conditions (e.g., current status, regulation, policy drivers) may influence the set-up choices for the procurement process design. However, the market-based procurement through local flexibility markets that involve the DSO or the TSO, or both, utilizing auction-based markets is of primary interest.

Reviewing these previous projects concerning the flexibility procurement process implemented in them has shown the need for a standardised or, at least, harmonised vocabulary. For instance, it has been challenging to apply the CoordiNet market model framework to projects that have not been designed according to that modelling approach. Even if, among the projects reviewed, the CoordiNet market framework considers the largest range of TSO-DSO market models, therefore it constitutes the starting point for OneNet. In addition, the review of the projects has revealed the effectiveness of the CoordiNet market model framework in describing initiatives not belonging to the CoordiNet project. Therefore, the CoordiNet market model framework can be considered a reliable starting point for describing the flexibility procurement process.

The defined coordination schemes in CoordiNet project are equivalent to some defined CEDEC et al. [49] and INTERRFACE project as shown in Table 2-15 [50]. The CoordiNet schemes are considered the reference for this report as it provides more options than CEDEC et al. and INTERRFACE.

Notwithstanding the validity of the CoordiNet market model framework, the project review stressed its gaps. CoordiNet market model framework focuses on the TSO-DSO interactions, but it does not comprehensively describe the flexibility procurement process. Therefore, the third step of the project review is devoted to identifying those aspects that can fill the CoordiNet market model framework gaps. The four elements of the CoordiNet market model framework and additional descriptors such as the procurement mechanism, pricing method, and procurement timeframe can provide a comprehensive picture of the flexibility procurement

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process. Hence, the analysis of these aspects shall represent the basis for designing and analysing the approaches to procure flexibility from third-party resources.

Table 2-15. Coordination schemes in CoordiNet and INTERRFACE compared to CEDEC et al. [49] report. Source: [51].

CEDEC et al. [49]	CoordiNet	INTERRFACE
Option 1A	• Multi-level market model, • Fragmented market model, • Central market model, • Local market model	• 1A • 1B • 1C
Option 2	• Common market model, • Integrated market model,	• 2A • 2B
Option 3	• Common market model, • Integrated market model,	• 3A • 3B • 3C • 3D
Out of scope	• Local market model • Distributed market model • Central market model	

Finally, the project review activities make the basis for discussing the formalisation of applying the theoretical market framework presented in section 3 and the analysis of the flexibility procurement process corresponding to the OneNet demonstrators described in section 4. In particular, the project review has been fundamental for developing the questionnaire in Annex II used to collect the relevant information from the OneNet demonstrators and guide the discussion on the procurement process topic, whose outcome is presented in section 4.

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3 Theoretical market framework

After surveying previous projects, the next task in this WP was to define a theoretical market framework for existing and novel market design options based on previous and ongoing projects and initiatives. This framework should be used to describe and define high-level coordination models, and, more specifically, market models. The goal of the market framework is (i) to clearly and precisely categorize the market concepts which will be studied in the project and tested in the demonstrators and (ii) ease the communication on the concepts both internally and externally.

In SmartNet project, coordination schemes are defined as 'the relationship between TSO and DSO, defining the roles and responsibilities of each system operator when procuring and using system services provided by the distribution grid' [52]. Moreover, the authors state that the level of coordination can be increased (i) through the assignment of responsibilities to system operators and the interaction between them and (ii) by focusing on specific market phases and how these should be organized through a proper market design. In OneNet, following the overall WP3 objective, we extend the SmartNet definition by looking at the relationship between all market parties, i.e., TSO, DSO, and flexibility providers (e.g., suppliers, aggregators, active customers. Thus, the scope is not only on system services provided by parties connected to the distribution grid but also focus on those provided by parties connected to the transmission grid within and across countries[9] (where applicable).

One of the goals of the market framework is to ease communication on market design. Therefore, to develop a framework that is clear and concise, we have decided to limit the framework within OneNet to (i) those mechanisms to provide system services only, i.e., no wholesale energy markets such as forward, day-ahead and intraday markets)[10], (ii) those mechanisms where TSOs and DSOs are the primary buyers of system services[11], and (iii) market-based markets solutions only[12].

3.1 Flexibility mechanisms

Flexibility can be acquired or achieved by system operators through different mechanisms. The report by CEDEC et al. [49] on 'An integrated approach to active system management with the focus on TSO-DSO coordination in congestion management and balancing' identifies five flexibility mechanisms that complement the list already provided in section 2.6 [49], [53], [54].

[9] Please note that the extent to which we broaden the coordination also depends on the business use cases (BUCs) developed by the demos in WP 7 to 10.
[10] The main focus is on system services. If, however, there is a linkage between the provision of system services and an energy wholesale market, this energy wholesale market will be included in the framework.
[11] However, exceptions can be made in the case that buyers are commercial parties, e.g., if energy markets are included as a sub-market.
[12] Based on the BUCs presented by the OneNet demos[12], the choice was made to only focus on market-based solutions.

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- **Technical solutions using grid assets**: the grid topology reconfiguration to alter power flows, including reactive power flows, and achieve a more desirable system state.
- **Rule-based solutions**: flexibility is imposed through rules and connection agreements. For instance, the curtailment of wind power is a rule-based solution to tackle congestion management.
- **Tariff solutions**: used to trigger implicit[13] flexibility that can react to prices. An example is a dynamic tariff which involves devising and implementing time (and location) differentiated network tariffs which can be adjusted to reflect the necessary temporal and spatial cost variations. The grid users are incentivised to change their consumption and/or production according to the grid operation situation and future network needs
- **Connection agreement solutions**: agreements with certain grid users so that their power injection or withdrawals can be limited under specified conditions. An example is a dynamic connection agreement between the SO and the FSPs. The latter agrees to have the connection curtailed in some periods. For example, demand could be temporarily reduced during the periods of peak demand, whereas generation could be curtailed to avoid network constraint violations, such as congestion or voltage issues. This mechanism refers exclusively to new connections to the electrical grid.
- **Market-based solutions**: explicit[14] procurement of flexibility from market parties in a market settlement.

With regard to market-based solutions, the Electricity-Directive of the Clean Energy Package [11] states that:

- 'TSOs shall procure balancing services subject to transparent, non-discriminatory and market-based procedures' (Art. 40, §4). This applies as well to the provision of non-frequency ancillary services unless 'the regulatory authority has assessed that the market-based provision of non-frequency ancillary services is economically not efficient and has granted a derogation' (Art. 40, §5).
- 'DSOs shall procure flexibility services following transparent, non-discriminatory and market-based procedures unless the regulatory authorities have established that the procurement of such services is not economically efficient or that such procurement would lead to severe market distortions or higher congestion' (Art. 32, §1).

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[13] Implicit (or price-based) mechanisms refer to the prosumers' reaction to price signals. As implicit mechanisms reflect the variability on the market and the network, prosumers can adapt their behaviour (through automation or personal choices) to save on energy expenses by shifting their load and/or generation to periods with low/high energy prices, or low grid prices.

[14] Explicit (or incentive-driven) mechanisms, on the other hand, involve the provision of committed, dispatchable, flexibility that can be traded on the different energy markets (wholesale, balancing, congestion management, etc.). Because this type of flexibility is dispatchable, and can be tailored to the markets' exact needs (size and timing), it may offer specific added value for e.g. balancing and capacity management [47], [48], where the system flexibility requirements are determined in advance.

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Additionally, the EU Regulation on the internal market for electricity [[55], Art. 13, §3] states that non-market-based re-dispatching[15] of generation, energy storage and demand response may only be used where (i) no market-based alternative is available; (ii) all available market-based resources have been used; (iii) the number of available power generating, energy storage or demand response facilities is too low to ensure effective competition in the area where suitable facilities for the provision of the service are located; or (iv) the current grid situation leads to congestion in such a regular and predictable way that market-based re-dispatching would lead to regular strategic bidding which would increase the level of internal congestion and the Member State concerned either has adopted an action plan to address this congestion or ensures that minimum available capacity for cross-zonal trade is in accordance with Article 16(8).

Market-based procurement relies on procuring services following a market-based procedure where flexibility is provided and allocated explicitly [43]. This procurement can take place in several ways.

Table 3-1. Overview of market-based solutions for the provision of flexibility

Flexibility mechanism	Number of buyers	Number of sellers	Price negotiation possible	Centralized market	Direct buyer and seller trading
Bilateral transaction	1	1	Yes	No	Yes
Auction market	1[16]	>1	No	Yes	No
Exchange market[17]	>1	>1	No	Yes	No

First of all, a **bilateral transaction (over-the-counter - OTC)** takes place between one buyer and one seller. It is used to set -up direct trading between two private parties at negotiated prices. Next, an **auction market** tender is a market where all traders in a commodity meet at one place or communicate with a central auctioneer to buy or sell a product. Our market framework defines an auction market as an interaction between one buyer and more than one seller[18]. There is no price negotiation possible and no direct trading between parties, meaning that a market operator is involved as a central counterparty (i.e., no direct trading between buyers and sellers, e.g. European power exchanges). An example of an auction market is the one for mFRR, where the TSO is the single buyer and multiple FSPs are the sellers. Finally, an **exchange market (discrete and continuous)**, or

[15] Redispatching means 'a measure, including curtailment, that is activated by one or more transmission system operators or distribution system operators by altering the generation, load pattern, or both, in order to change physical flows in the electricity system and relieve a physical congestion or otherwise ensure system security'[[55], p. 66]

[16] In the case of joint procurement by multiple SOs, the different SOs are regarded as one entity and hence can be seen as a single buyer.

[17] Market clearing can be discrete (e.g., day-ahead market) or continuous (e.g., intra-day market).

[18] This is sometimes referred to as a 'single-buyer auction'.

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also called a power exchange in power systems, is a centralized market where the bids specify price and quantity or a supply or demand curve.

The market-based flexibility options mentioned above can be combined as 'sub-markets' into an 'entire market'. This construction, then, represents the market architecture on which the theoretical framework will be applied.

3.2 Market architecture

According to Stoft [23], the market architecture is the 'map of the entire market's component sub-markets including the type of each sub-market and the linkages between them'. We apply the theoretical market framework to this entire market. The market architecture is characterized by the market type of each sub-market and the linkages between the sub-markets. According to D3.2 from Magnitude, a sub-market is assumed to be operated by one market operator responsible for the market-clearing of this specific market according to a specific objective [22]. Moreover, the Active System Management report defines a (sub-) market as a Merit Order List combining specific products for a specific timeframe [49]. The **market type** refers to the type of flexibility mechanisms used in the respective sub-markets (see Section 3.1)[19]. The **linkages** between the sub-markets can be spatial, temporal, etc. Moreover, they can be implicit or explicit. For instance, implicit price relationships can be caused by arbitrage, while explicit rules can link rights in one market to activity in another market. Figure 3-1 shows a graphical representation of the market architecture of the 'entire market' (orange box), made up of 2 'sub-markets' (green boxes) and their linkages (red line).

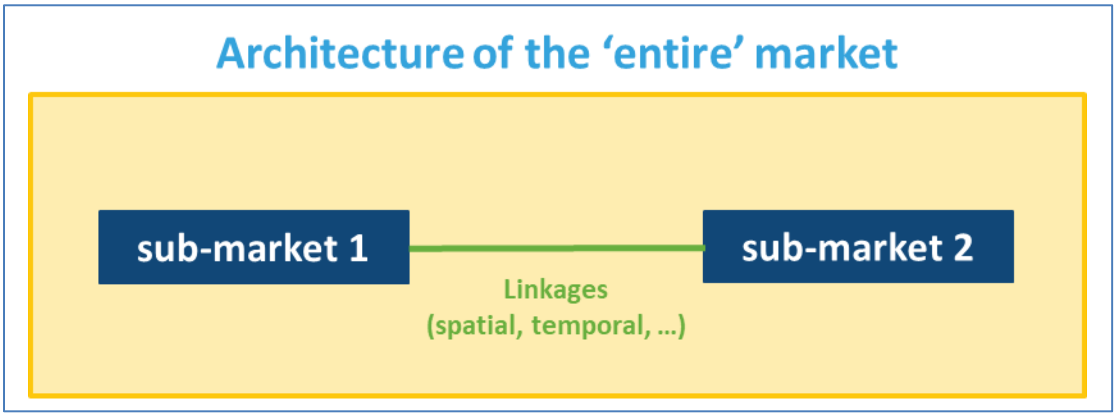

Figure 3-1. Example of the marker architecture to which the theoretical market framework will be applied

The market architecture can be applied at different levels. For instance, the entire market could be the balancing market, where the markets for FCR, aFRR and mFRR then constitute sub-markets within the entire balancing market. Or, at a higher level, the entire market could be the ancillary services market, which in turn is

[19] Theoretically speaking, implicit flexibility mechanisms are not markets. However, since, in the OneNet theoretical market framework, we will limit ourselves to explicit flexibility mechanisms (see Section 3.1), we keep using the term 'market type' as described by [23].

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composed of the balancing market, congestion management market, voltage control market, etc. as sub-markets.

‘Coordinated and integrated markets’, as mentioned in the objective of WP3, hence, refers to the way sub-markets are operated in connection with each other making an ‘entire market’ and to the way coordination happens within and among sub-markets.

3.3 Theoretical market framework

Figure 3-2 presents the theoretical market framework applied to the entire market, which consists of sub-markets. Please note that the theoretical market framework is developed only for market-based procurement of flexibility. The theoretical market framework consists of five pillars: dimensions of coordination, coordination between sub-markets, market optimization, market operation, and grid constraints representation. Each of the pillars is further defined by several features and each consists of many attributes. While the first two pillars set up the structure of the entire market (consisting of sub-markets) and define the nature of the coordination, the last three pillars describe the dimensions of market clearing. In the following sections, the five pillars are described in detail.

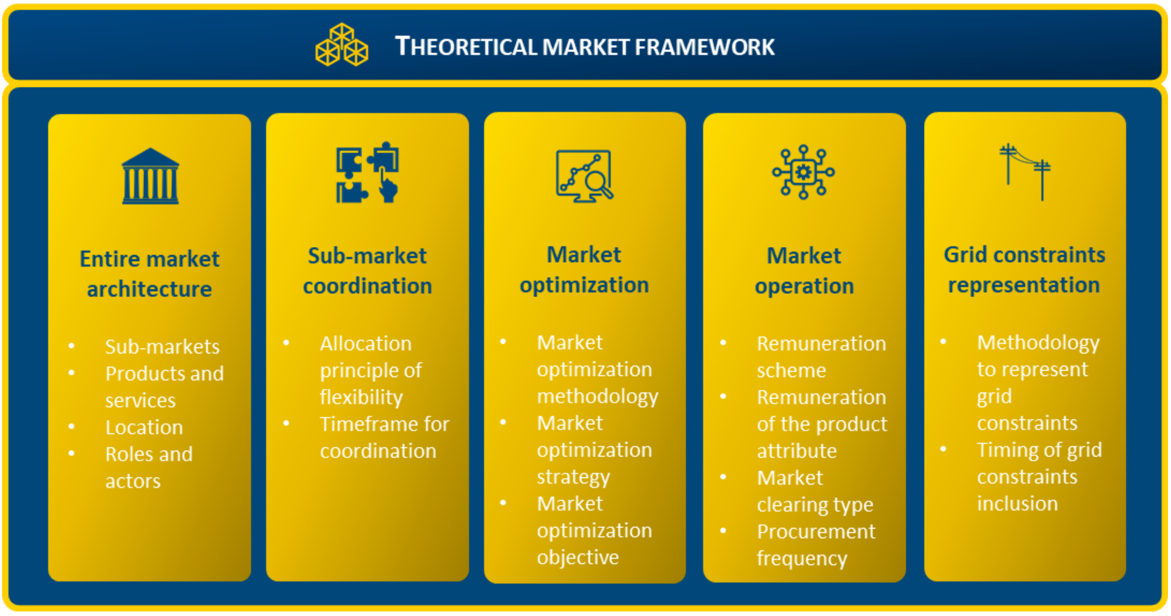

Figure 3-2. Theoretical market framework

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3.3.1 Entire market architecture

The first pillar describes the architecture of the entire market (consisting of sub-markets).

Figure 3-3 shows a graphical overview of this first pillar and the different features comprising it. Every feature consists of several attributes. For example, the block's colour shows to which market-level it applies for each feature, i.e., to the entire market (yellow blocks) or the sub-markets (blue blocks).

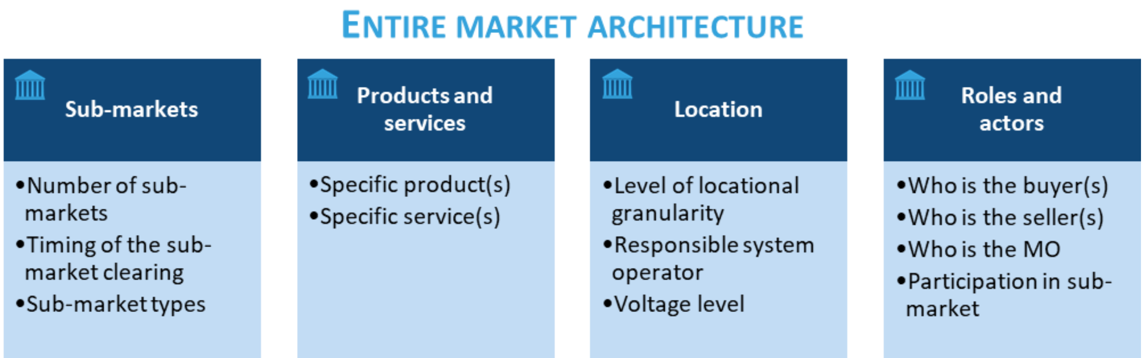

Figure 3-3. Detail of 'Entire market architecture' pillar

The first feature is the **sub-markets**. It applies to the entire market and describes the following attributes: the number of sub-markets, the timing of the sub-markets, and the type of each sub-market. The timing of the sub-markets refers to when these sub-markets take place, i.e., the GOT, GCT, and timing for publication of the market outcome, and, hence, captures the temporal linkage between different sub-markets. This linkage then contributes to the definition of the entire market. The sub-market types refer to the types of market-based solutions used in the respective sub-markets to acquire flexibility (i.e., bilateral negotiation, auction, or exchange market).

The second feature is the **products and services**. It can be applied to each sub-market and concerns which specific product(s) and service(s) are marketed in that sub-market. Products and services are discussed in more detail in Deliverable 2.2 of the OneNet project. That deliverable has developed a framework for services and products, the latter of which is shown in Table 3-2 and Table 3-3. Moreover, in the same deliverable, several harmonized products were proposed, i.e., inertia, FFR, FCR, mFRR, near-real-time operational local active power, short-term local active power, long-term local active power, near-real-time operational local reactive power, short-term local reactive power and long-term local reactive power. Therefore, within the framework of OneNet, the specific product(s) and service(s) should be selected from the options proposed in OneNet Deliverable 2.2.

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Table 3-2. The framework for products developed in D2.2 of OneNet - attribute set by SO/MO

	Objective of the product					
	Technical dimensions The network operator aims to operate the network efficiently and reduce the overall cost of network operation and planning. To achieve this, the network operator will define technical requirements for the traded products and the market mechanism.			Bid related dimensions The bid related dimension of a flexibility product reflects the rules introduced in the bid as part of the procurement process.	
	Definition of the good traded Characteristics of the "good" being acquired by the SO	Timing for delivery Description of the timing in the delivery of the product	Communication Methodology used to communicate between SO an FSP	Technical rules for the bid Limitations in the structure of the product	Settlement rules Measures linked with the way that companies will be paid
Choices SO/MO do in attributes	Capacity / energy	Maximum preparation period	Required mode of activation	Minimum quantity	Baseline methodology
	Active/reactive energy	Maximum ramping period		Divisibility (Y/N)	Measurement requirements
	Location information required (Y/N)	Maximum full activation time		Granularity	Penalty for non-delivery
	Certificate of origin (Y/N)	Duration of delivery period		Maximum and minimum price	
	Minimum level of availability	Maximum deactivation period		Availability price (Y/N)	
	Symmetric/asymmetric product (Y/N)	Maximum recovery period		Activation price (Y/N)	
	Validity period of the bid	Maximum number of activations		Aggregation allowed (Y/N)	

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Table 3-3. The framework for products developed in D2.2 of OneNet - attribute set by FSP

	Objective of the product				
	Technical dimensions			Bid related dimensions	
	The network operator sets the limits for the attributes they require. It is for the FSP to determine the actual value they are able to provide for these attributes.			The bid related dimension of a flexibility product reflects the rules introduced in the bid as part of the procurement process.	
	Definition of the good traded	Timing for delivery	Communication	Technical rules for the bid	Settlement rules
	Characteristics of the "good" being acquired by the SO	Description of the timing in the delivery of the product	Methodology used to communicate between SO an FSP	Limitations in the structure of the product	Measures linked with the way that companies will be paid
Choices FSPs do on attributes	Location of delivery	Preparation period for the FS		Availability price	
	Level of availability	Ramping period for the FS		Activation price	
	Certificate of origin	Full activation time for the FS		Divisibility (If SO accepts- Y/N)	
	Quantity upwards	Offered duration of delivery period			
	Quantity downwards	Deactivation period			
		Recovery period			
		Maximum number of activations (per day, week…) offered by FS			
		Availability window (per day, per week, per year) offered by FS			

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The third feature is the **location** and, like products and services, is applied to each sub-market. First of all, the locational granularity level measures the size of the specific independent areas considered for the flexibility procurement (i.e. the network areas that contain the FSPs that can potentially contribute to solving the system need). In the context of power systems, the locational granularity can be used in terms of nodes, voltage levels, and feeders. There are several options which concern the locational granularity aspects. On the one hand, users can be classified depending on the nodal or zonal pricing approaches. Nodal pricing is a fully granular option for setting customer-specific prices for grid users. On the other hand, zonal prices are a less granular option which would involve setting prices on a zonal basis[20] to reflect variations of power flow and network constraints within each zone. More granular prices could be achieved regarding nodal granularity (primary or distribution substation level) to improve cost reflectivity below the point at which a customer-specific price is applied. Then, for each market, the responsible system operator (SO) must be defined. It can be the TSO or the DSO. If both TSO and DSO are present in the market, then both should be mentioned. We refer to the actor who takes up the role of System Operator and not of Market Operator (MO)[21] because, in this feature, our interest goes to the grid where the flexibility is acquired, and, hence, to the SO who is responsible for this grid. We are not looking at who is responsible for running the sub-market (i.e., the MO). Finally, for each sub-market, the voltage level(s) where flexibility will be procured needs to be defined. Depending on the product and the service, this can be limited to one voltage level only or multiple voltage levels.

The fourth feature looks at the market **roles and actors** involved in each sub-market. It defines the actor(s) who buy and sell flexibility and who takes up the role of MO for each sub-market. Also, it looks at the participation in the sub-market to see if it is optional, compulsory, or a hybrid form. Optional participation means that BSPs or FSPs[22] can choose to participate in the sub-market or not. Compulsory means that under certain circumstances, certain parties might be obligated to participate in the sub-market. For instance, in Italy, generators larger than 10 MW are obligated to participate in the ancillary services market. However, since a couple of years, new sources of flexibility are also allowed to participate in that same market[23]. Their participation is voluntary. In this specific case of the ancillary services market in Italy, participation can be both compulsory and voluntary. Hence, a hybrid form of participation exists. The 2021 ENTSO-E survey on ancillary services and balancing market design provides an overview of market participation in the different European countries for several ancillary services [56].

[20] These prices could be based on marginal pricing or pay-as-bid. For more information on the type of remuneration scheme, see Section 3.3.4,

[21] A **role** represents the external intended behaviour of a party. Roles describe external business interactions with other parties in relation to the goal of a given business transaction. Parties carry out their activities by performing roles, e.g. system operator, trader. Parties cannot share a role. An **actor** represents a party that participates in a business transaction. Within a given business transaction an actor assumes a specific role or a set of roles. An actor is a composition of one or more roles and as such does not appear in the model.

[22] In the case of ancillary services, it is always the participation of the seller, i.e., the FSP which can be optional or compulsory. However, the same might not be the case for other (non-power or service) markets.

[23] See the discussion paper Italian Regulatory Authority for Energy, Networks and Environment (ARERA) of 23 July 2019, DCO 322/2019/R/eel, Testo Integrato del Dispacciamento elettrico (TIDE) - Orientamenti complessivi.

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3.3.2 Sub-market coordination

The second pillar describes the coordination between the sub-markets in the entire market. Figure 3-4 shows a graphical overview of the second pillar and the different features comprising it. For each feature, the block's colour shows to which market-level it applies, i.e., to the entire market (yellow blocks) or the sub-markets (blue blocks). Thus, the features in this pillar both apply to the entire market.

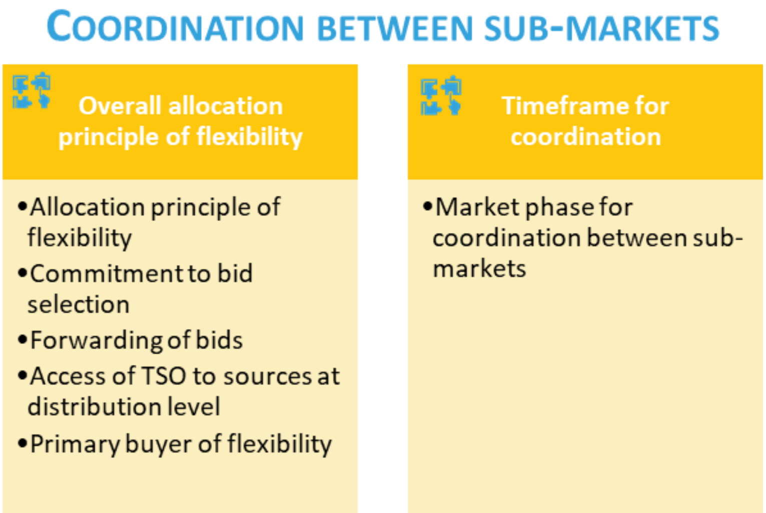

Figure 3-4. Detail of 'Coordination between sub-markets' pillar

The first feature is the **allocation principle of flexibility.** The allocation principle is used to determine how the amount of flexibility at the transmission or distribution level is divided between the different services and/or system operators and sub-markets. Thus, the allocation principle does not apply as one principle to the entire market, but is linked between two sub-markets. Moreover, the allocation principle only applies when resources are procured in the same time window. Figure 3-5 presents a flow chart for determining the allocation principle, while Figure 3-6 provides an example to illustrate the determination of the allocation principle.

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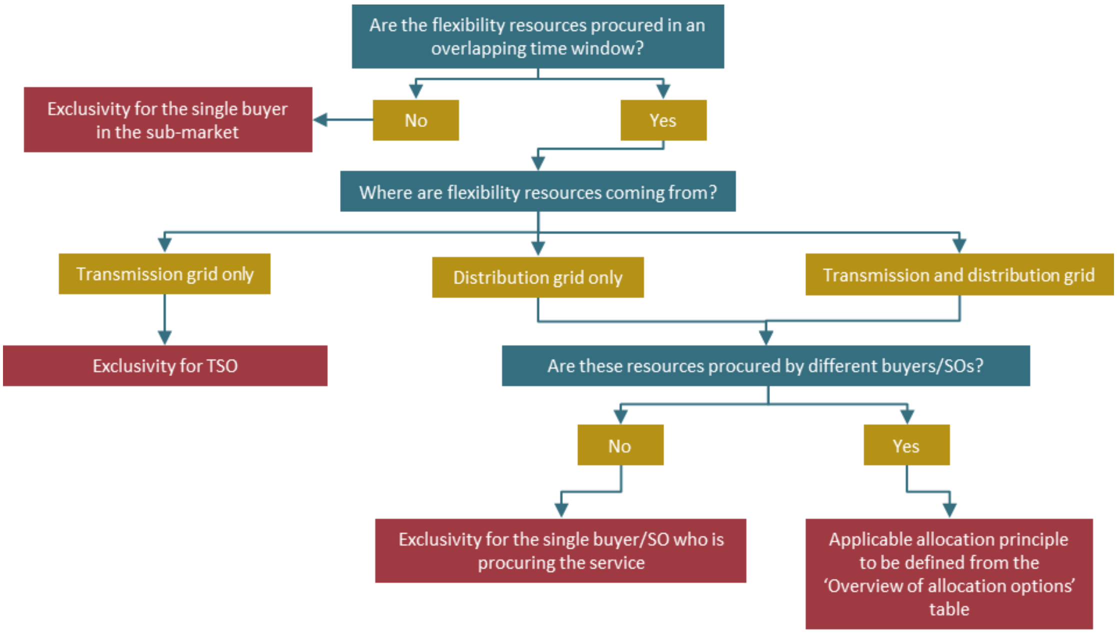

Figure 3-5. Flow chart for determining the application of the allocation principle

Figure 3-6 shows an example of an entire market of four sub-markets (green blocks), shown in their respective timing.

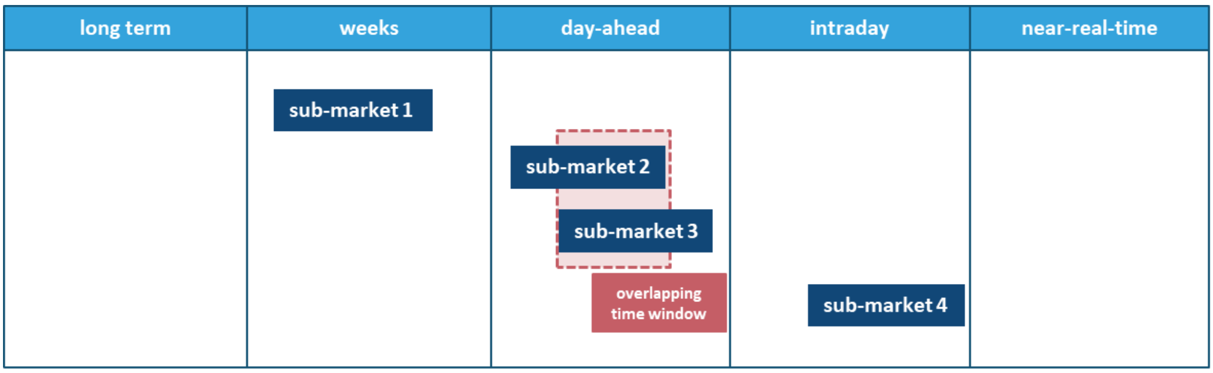

Figure 3-6. An 'entire market' made up of four 'sub-markets' (blue blocks), shown in function of their respective timing

According to the flowchart in Figure 3-5, sub-markets 1 and 4 do not procure flexibility in time windows overlapping with other sub-markets. Therefore, the allocation principle is 'exclusive use for the single buyer'. This single buyer can be a TSO, DSO or another buyer. Only sub-markets 2 and 3 take place in an overlapping time window. Depending on the provenance of the flexibility resources and the fact if the resources are being procured by the same or different buyers, a different allocation principle can apply. The different options for the allocation principle are shown in Table 3-4.

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Different options are possible within the allocation principle, i.e., priority for the TSO, priority for the DSO, exclusive use for the TSO, exclusive use for the DSO, and no priority or exclusivity for TSO or DSO. In D3.2 of EU-SysFlex, these options were described differently[24], namely:

- **Bottom-up coordination**: optimization at the distribution level, followed by optimization at the transmission level. This type of coordination leads to the optimal selection of bids where there is a separate optimization of products and radial distribution grids. This scheme is equivalent to a combination of 'priority for the DSO' and decentralized optimization (see Table 3-4).
- **Hybrid coordination**: optimization at the distribution, followed by optimization at the transmission, and again at the distribution level. The hybrid approach can be more efficient where there is a joint optimization of different products or meshed distribution grids with specific combinations of local grid structures, power flows, and characteristics of flexibilities (such as location, voltage level and price).
- **Top-down coordination**: optimization at the transmission level, followed by optimization at the distribution level. Top-down coordination only works for balancing products, if there is no need to limit the flexibility activation in the operational phase at the distribution level (due to firm connection agreements or prequalification).

These three options and their integration in the theoretical framework result from the combination of the allocation principle and the market optimization methodology. Bottom-up coordination is a combination of 'priority for the DSO' and decentralized optimization, top-down coordination is a combination of 'priority for the TSO' and decentralized optimization. Hybrid coordination is a combination of 'no priority' and decentralized optimization.

Moreover, depending on the selection of the allocation principle option, other features linked to this option are automatically decided. These features are the commitment of bid selection, the forwarding of bids, whether the TSO has access to resources at the distribution level and who the main buyer of the flexibility is. For instance, the allocation principle option 'priority for DSO' automatically implies that the commitment to bid selection is formal, that bids will be forwarded, that the TSO has access to FSPs at the distribution level and that the primary buyer of the flexibility is the DSO. Therefore, these features are not included explicitly in the framework but can be found in Table 3-4.

[24] Additional information on these coordination options can be found in D3.2 of the EU-SysFlex project [57].

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The selection of bids can take place with formal or conditional commitment [52]. It is important here to note that selection of bids has no relation to grid constraints. Instead, the selection of bids refers to who can use the offered flexibility, while already accepting the current constraints and not causing new problems in the SO grids. Formal commitment means that the offered flexibility can be used by the SO with priority or exclusivity while respecting the constraints of the other SOs whose grid might be impacted. Conditional commitment refers to a common market model as defined in SmartNet. SmartNet distinguished two variants of this common market model. In the first variant, all bids are offered and cleared in one market session, considering transmission and distribution grid constraints simultaneously[25]. In the second variant, it is assumed the market is organized in a decentralized way. Conditional commitment to bid selection then refers to the fact that a particular local market is run first. It is operated by the DSO, for local DSO needs, and considers local grid constraints, but without any formal commitment to the market participants. The preliminary results are shared with the TSO market and integrated into a second market optimization that considers the system objectives. Based on the outcome of the second optimization, a communication is sent to the local market specifying which bids are accepted and for whom (for the DSO or the TSO). Another implicit feature is the forwarding of bids. Bids can be forwarded from one sub-market to another or not. For instance, a DSO clears a sub-market to manage congestion at the distribution level. Bids that are not accepted in this sub-market could be automatically forwarded to congestion management or balancing sub-market at the transmission level. Moreover, the selection of allocation principle will decide whether the TSO has access to the resources at the distribution level and who the primary buyer of flexibility is. The different options for the allocation principle are discussed below.

[25] The drawback of this system might be that, in cases where the market is large and multiple bids are offered, the optimization process becomes mathematically heavy.

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Table 3-4. Overview of the allocation principle options and their implications

Allocation principle of flexibility	**Commitment to bid selection**	**Forwarding of bids**	**TSO has access to sources at the distribution level**	**Primary buyer of flexibility**
Priority for TSO	Formal	Yes	Yes	TSO
Priority for DSO	Formal	Yes	Yes	DSO
Exclusive use for TSO	Formal	No	Yes	TSO
Exclusive use for DSO	Formal	No	No	DSO
No priority or exclusivity for TSO or DSO	Conditional in decentralized optimization Formal in centralized optimization	Yes	Yes	TSO and DSO

First of all, there can be a priority for the TSO. This means that the TSO is the first to choose the sources of flexibility. The FSPs can be located at the distribution or transmission level. Acceptance of bids is formal. Bids are forwarded to other sub-markets as the TSO has priority but no exclusive use over the bids. Priority can also belong to the DSO, and this means that the DSO is the first to choose the sources of flexibility to use to provide a particular service. These sources are located at the distribution level only. Acceptance of bids is formal. Bids can be forwarded to other sub-markets as the DSO has priority but no exclusive use over the bids. A third option is exclusive use for TSO; where the TSO is the only one who has access to the bids. Acceptance is formal, and rejected bids are not forwarded to other markets. This option is standard for transmission-connected resources as these can only be used by the TSO. Exclusive use of flexibility can also be allocated to the DSO. In this case, the DSO is the only one to have access to the bids. Similar to the previous case, acceptance is formal and rejected bids are not forwarded. The final option states no priority or exclusivity for TSO or DSO. In this case, the acceptance of bids is conditional in a decentralized optimization (i.e., more than one sub-market) and formal in a centralized optimization (i.e., only one sub-market). Rejected bids can be forwarded. In this case, the market objective (of the entire market) maximises social welfare or minimises total costs.

The second feature in this pillar is the **timeframe for coordination**. First of all, it is essential to note which market phase of each sub-market the coordination will take place. This refers to a temporal linkage between the sub-markets (see Section 3.2). For example, the market phase can be pre-qualification, procurement, monitoring and activation, and (to a lesser extent) measurement, activation, and settlement control.

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3.3.3 Market optimization

The third pillar describes the market optimization. The first two features apply to the entire market, while the latter applies to the individual sub-markets. Figure 3-7 shows a graphical overview of this third pillar and the different features it comprises. The block's colour shows to which market level it applies for each feature, i.e., to the entire market (yellow blocks) or the sub-markets (blue block). While in the first and second pillars, each feature consists of several attributes which, in turn, have many options to choose from, the third pillar only has one layer of features and the possible options are presented explicitly.

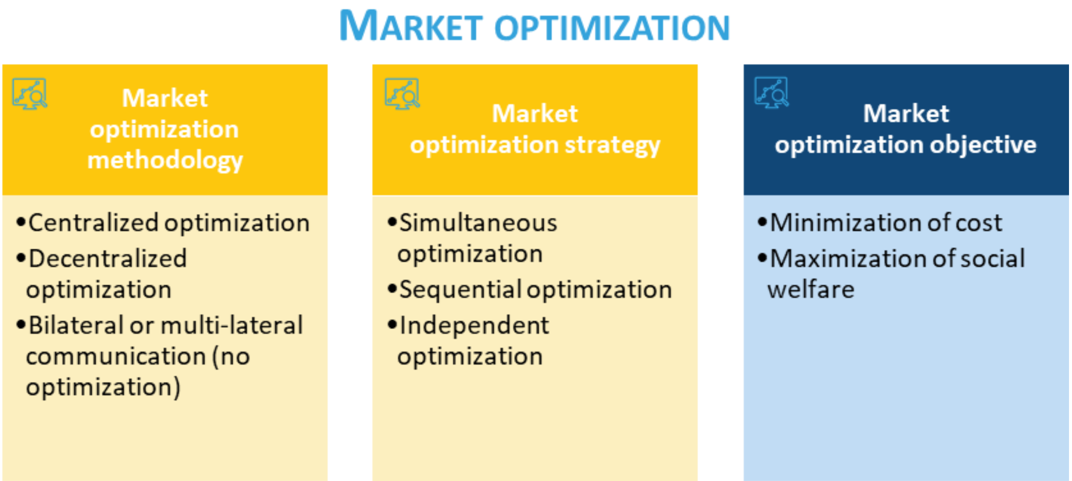

Figure 3-7. 'Market optimization' pillar options

The first feature is **market optimization methodology** and describes the different options for market optimization between two sub-markets. We distinguish three possibilities, i.e., centralized and decentralized optimization, and distributed organization. In EU-SysFlex, a detailed description of these three options was provided and is taken over in this document [57]. First of all, in centralized optimisation one algorithm considers all voltage levels, including both transmission and distribution levels. An important choice that needs to be made relates to the kind of grid data sent by each SO to the actor in charge of optimization (typically the market operator - MO, or the optimization operator - OO) to take the grid constraints into account[26]. All necessary data (bids, reserve needs, comprehensive or partial grid data or bid limitations where possible) are directed into a single algorithm to consider constraints at all voltage levels and select the most appropriate bids. In the case of comprehensive grid data, the algorithm also selects the optimal switching measures. Therefore, one optimization for all system operators solves all their system needs. Conceptually, a centralized optimization leads to an optimal allocation of resources at the system level. Other advantages of a centralized optimization

[26] This choice is in itself also a feature in this third pillar and is explained further down in the text.

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lie in reduced coordination effort and lower interoperability challenges. However, there are challenges, among them the complexity of the algorithm.

In decentralized optimization, several algorithms optimize for different levels (run by the respective OO who executes the optimization for each SO), hence at least one for the transmission level, and one for the distribution level and require to be coordinated. There is one optimization for each SO to procure its system needs. Then, coordination is needed between the different optimization levels.

According to EU-SysFlex, decentralized optimization appears more relevant for grids where DSOs need locational products to solve voltage and congestion problems [57]. Other advantages of decentralized optimization include the higher resilience, lower complexity of individual algorithms, the possibility to adapt individual optimizations to specific requirements (voltage level, region) and the better fit to the current regulatory framework, including the subsidiarity principle. On the other hand, challenges for decentralized optimization mainly include the coordination between the different OOs and the potential reduction in efficiency as compared to the centralized case.

In a distributed market organization, there is no (externally driven) optimization [57]. It is a particular case of a decentralised market organization where all the MOs share relevant information. Although each of the MOs can have their objective, they can ensure convergence towards a joint objective function via, e.g., a decomposition coordination mechanism[27]. Another possibility for implementing a distributed market structure is a peer-to-peer market setup, in which no decomposition coordination mechanism is in place. Hence, there is no need for the introduction of a master/centralised entity [22]. An example of a distributed market organization is a peer-to-peer market. This market model is based on 'peers directly negotiating with each other to sell and buy electric energy. Hence, two peers can agree on a transaction for a certain amount of energy and a price without centralized supervision' [58].

The second feature in this pillar looks at the **market optimization** applied for entire markets with more than one optimization, for instance, in the case of more than one sub-market, or for one sub-market which procures two products through separate optimization schemes. It looks at two sub-markets linked following a pre-set scheme and defines how the joint optimization between these two markets occurs[28]. Simultaneous optimization means that both markets are optimized simultaneously while sharing resources, e.g., the US's joint optimization of energy and reserve markets. Sequential optimization means that one market is optimized before the other,

[27] However, if a decomposition coordination mechanism is in place, there is a potential need for a centralised entity that guarantees that the output of the distributed markets converges to the defined common objective.

[28] We make the distinction between joint procurement and joint optimization. In D3.2 of EU-SysFlex, three types of joint procurement were defined. The first type is coordinated procurement by TSOs and DSOs of a certain type of product to solve one specific type of scarcity. and can take place in a centralized (simultaneous) or decentralised (sequential) optimization. The second type of joint procurement is the use of one product to solve more than one scarcity, either by one or more buyers. The third type of joint procurement is the procurement of two or more products by one or more buyers to solve one or more scarcities. For the second and third type of joint procurement, the optimization process across the scarcities can be simultaneous or sequential.

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e.g., optimizing energy and reserve markets in Europe. Independent optimization means that markets are cleared simultaneously (in parallel, rather than jointly) while only sharing some clearing constraints (if needed) rather than sharing resources (i.e., bids). The link with the previous block can also be made. For instance, if two sub-markets are optimized in a centralized way, they are also optimized simultaneously. In the case of decentralized optimization, sub-markets are cleared sequentially or independently.

The third feature is the **(sub-) market optimization objective** feature. Sub-markets can be optimized according to maximization of social welfare or minimization of costs. Maximizing social welfare means maximizing the producer (FSP) and buyer (SO) surplus. When there is no (complete) information about buyer-side willingness to pay, cost minimization may be an alternative to the market instead of maximizing social welfare.

3.3.4 Market operation

The fourth pillar describes the market operation. All features in this pillar apply to the individual sub-markets (green blocks). Figure 3-8 shows a graphical overview of the fourth pillar and the different features it comprises. While in the first and second pillar, each feature consists of several attributes with many options to choose from, the fourth pillar, like the third, only has one layer of features and the possible options are presented explicitly.

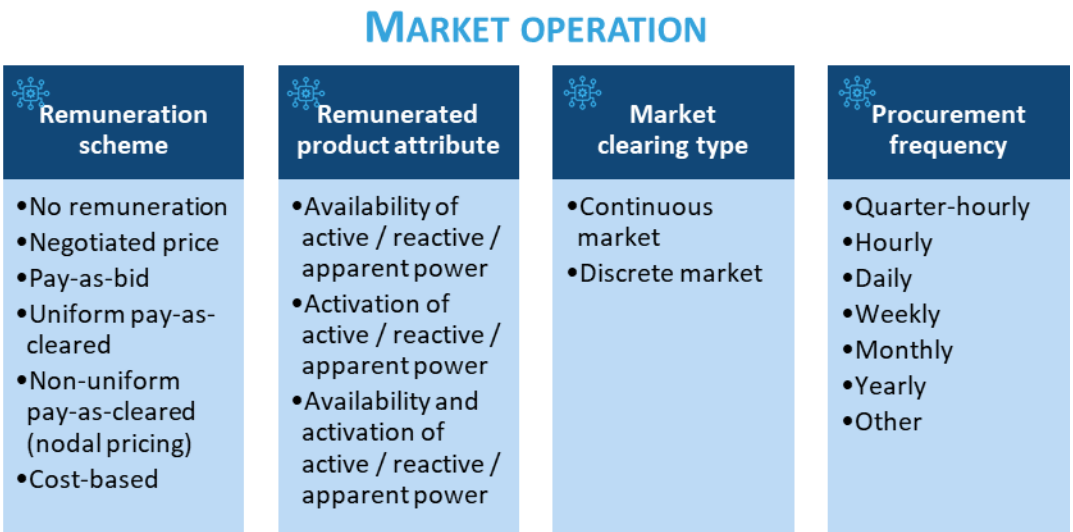

Figure 3-8. 'Market operation' pillar options

The first feature is the **remuneration scheme**. We distinguish six options: no remuneration, negotiated price, pay-as-bid, uniform pay-as-clear, non-uniform pay-as-clear (i.e., nodal pricing) or cost-based remuneration. When the trade happens through bilateral negotiation, the price is negotiated. The remuneration method 'pay-as-bid' (also called a 'discriminatory price auction') implies that each seller receives the payment for the offered good or service which is equal to the actual selling price asked [20]. Therefore, each accepted bid of the auction

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is remunerated differently. In a pay-as-bid scheme, accepted bids receive their bidding price [20]. The market price is thus different for market participants bidding at different prices. The remuneration method 'uniform pay-as-cleared' (also called a 'uniform price auction') implies that all the sellers receive the same unitary payment for the offered homogenous good or service. All sellers are paid according to the same per-unit price equal to the lowest accepted bid, regardless of the sellers' actual selling price. The market price corresponds to the intersection of supply and demand curves [20]. All supply orders below this market price (in-the-money) are accepted, whereas all supply orders above the market price (out-of-money) are rejected. Similarly, demand orders above the market price are accepted, whereas demand orders below the market price are rejected. Thus, the intersection between the demand and supply curve sets the cleared quantity, which is the traded volume. Non-uniform pay-as-cleared refers to nodal pricing, which is defined as follows: 'Nodal pricing is a method of determining prices in which market clearing prices are calculated for several locations on the transmission grid called nodes. Each node represents a physical location on the transmission system, including generators and loads. The price at each node reflects the locational value of energy, which includes the cost of the energy and the cost of delivering it (i.e., losses and congestion)' [59]. Nodal pricing can also be applied to the distribution grid. Remuneration can be cost-based [20], or even possible that the service provider is not remunerated at all. Regulated mechanisms can be alternative or complementary solutions to market-based solutions when they cannot work properly due to market failures (for instance, lack of sufficient flexibility providers to create a competitive market, as can be the case for re-dispatching in a location with structural congestions) or implementation costs. A cost-based remuneration is based on a determined price or price curve that the system operator sets for buying a service and potentially agreeing with the FSP on the specified quantity [20].

The second feature describes the **remuneration of the product attribute**. Remuneration can be provided for availability, activation, or both, for active, reactive, and apparent power. This feature generalises the definition of the product framework devised in OneNet 2.2 (Table 3-2). Regarding product definition, the description of the market framework only requires a high-level understanding of the exchanged and remunerated quantities. Considering the electric power system, all products regarding active and reactive power capacity are described in this deliverable as active and reactive power availability. Similarly, the products, including energy exchange or reactive power provision, are described in the present deliverable for active and reactive power activation.

The third feature looks at the **market-clearing type**. In a continuous market, a market participant can buy and sell assets at any given time. Traders who react first to a particular trading opportunity have a comparative advantage. Consequently, continuous trading generates incentives for each trader to become marginally faster than the competition. Market clearing following a discrete auction refers to a recurring, scheduled, frequent batch auction market where the respective market is cleared at discrete intervals (e.g., each quarter-hour) through a uniform auction [43].

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The fourth feature looks at the **procurement frequency**. This feature refers to how often the sub-market is run. The difference with the timing of the sub-markets is that, while the procurement frequency can be identical for different markets, they can still have different timing or GCT. For example, in Belgium, the FCR, aFRR and mFRR capacity (availability) market all have a daily procurement frequency. However, the GCT of the FCR market is before aFRR, the GCT of the aFRR market is before the one of mFRR market.

3.3.5 Grid constraints representation

The fifth pillar describes the representation of the grid constraints. Both features apply to the individual sub-markets. Figure 3-9 shows a graphical overview of this fifth pillar and the different features it comprises. As was the case for the third and fourth pillars, this last pillar only has one layer of features and the possible options are presented explicitly.

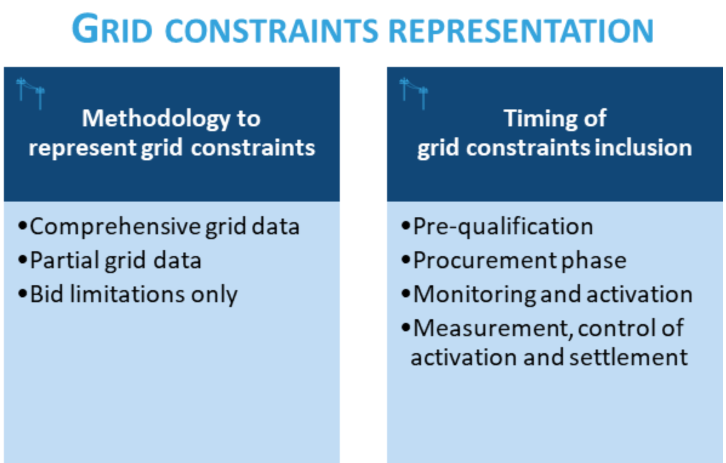

Figure 3-9. Detail of 'Grid constraints representation' pillar

The first feature describes the **representation of grid constraints**. EU-SysFlex [57] distinguishes three possible ways in which grid constraints can be taken into account. These methods are described below:

- **Comprehensive grid data:** describes the electrical properties of the grid to depict its dynamics. This way the optimization algorithm can calculate diverse grid phenomena, select the most efficient combination of flexibilities and switching of topology.
- **Partial grid data:** uses the sensitivities of flexibilities towards critical V/I constraints and V/I margins in the grid, e.g. for one topology.
- **Bid limitations only**: the SO reduces or rejects bids which, if accepted as submitted, would cause grid constraints to be violated. The bid limitations can be sent after a pre-selection step or before the selection led by the OO.

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The second feature is the timing of the inclusion of grid constraints. This refers to the market phase in which grid constraints are included, i.e., pre-qualification, procurement phase, monitoring and activation, and, control of activation and settlement.

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4 Mapping the market framework with the OneNet clusters

This chapter aims to apply the theoretical market framework developed in Chapter 3 to the different clusters of OneNet – Northern, Southern, Western, Eastern (Figure 4-1). The defined market models seek to cover the needs in terms of use cases, products, coordination with existing markets, and also country-specific aspects.

For this analysis, the questionnaire in Annex II was distributed to every OneNet demonstrator. In this questionnaire, multiple questions were made to map the previously presented theoretical market framework onto the demonstrators. Thus, a total of 14 questionnaires were received and analysed. These were commonly answered by each demonstrator's country (Spain, Czech Republic, Slovenia, Hungary, Cyprus, Portugal, Greece, Poland, France), except for the Northern cluster, that, due to having BUCs involving multiple countries, provided the answer to the questionnaire by considering a division based on products being assessed. Therefore, for the Northern cluster, the questionnaire answers have not been provided on a country basis.

At this stage of the OneNet project, it is understandable that the complete details of the different market models being developed by the demonstrators are not entirely defined as they will be the focus of future tasks of OneNet; this is considered and analysed. Notwithstanding, the information collected allows defining a firm picture of the activities and the market model framework of interest for each of the demonstrators. Even if some element of the market model developed by the demonstrator may evolve during the OneNet project activities, the fundamental aspects are firm; this grants the validity of the analysis and conclusions described in this section.

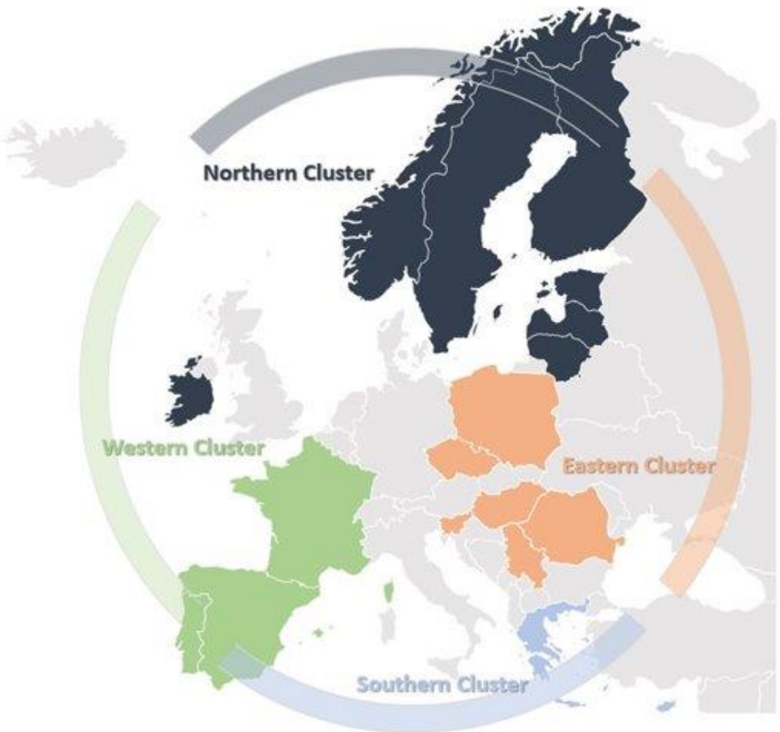

Figure 4-1. OneNet demonstrators' countries and corresponding cluster

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4.1 General description of the clusters market frameworks

4.1.1 Northern Cluster

Finland, Estonia, Latvia, and Lithuania are part of this demonstrator of OneNet. The Northern Demonstrator is an integrated effort by multiple TSOs and DSOs to enable market-driven flexibility uptake by these networks in a coordinated way through multiple markets where liquidity can be reached due to scope or existing trading volumes. Through this demonstration, the project will show mapping and management of network needs in multiple use cases over multiple networks. This cluster focuses on joint and shared mechanisms to be used by multiple networks and, therefore, on demonstrating the scalability and contribution towards a pan-European solution. Cross-border joint use cases are defined; therefore, country-specific market models coincide.

For this reason, the mapping of the theoretical market framework within the Northern cluster is unique for all countries. For clarity, the analysis of the market model of the Northern cluster is made on a time frame basis. Overall, the proposed submarkets include active and reactive power products, which the TSO and DSO can use for multiple needs, such as frequency control, voltage control, or congestion management. The developed market model is drafted paying special attention to the TSO-DSO coordination for flexibility procurement, therefore, providing a coordinated, flexibility enabled, market-based network operation. In the context of the present deliverable, the Northern cluster is of interest since the DSO market-based coordination is explored.

4.1.2 Southern Cluster

The objective of the Southern Demonstrator is to devise, develop, implement and evaluate two pilot projects in Greece and Cyprus dealing with balancing and congestion management challenges facing system operators in the clean energy era, in compliance with the OneNet overall architecture. The results will be evaluated to provide recommendations for future market reforms in the region and harmonise a pan-EU electricity market. The primary activity of the Greek demonstrator is the improvement of the procedures for congestion management resolution. The Greek demonstrator focuses on the technical-based TSO-DSO coordination based on the existing market architecture. On the other hand, the Cyprus demonstrator aims to provide an effective collaboration framework for the TSO-DSO-Consumer value chain and the energy market by developing an active balancing and congestion management platform. The Cypriot demonstrator includes the definition of a market-based TSO-DSO coordination.

4.1.3 Western Cluster

The Western cluster includes 3 countries - Portugal, Spain and France – and it has the overall objective of implementing a wide range of flexibility mechanisms, namely addressing DSO and TSO needs, including coordination between market mechanisms and the planning and real-time operation of the grids. Among the main goals to be achieved, increasing renewables and anticipating operating scenarios are relevant priorities.

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The Portuguese demonstrator focuses on defining the principles, information exchange, and submarket coordination to enhance the TSO and DSO operational planning activities, particularly focusing on congestion management. The Spanish demonstrator develops and tests a local market model to unlock the flexibility of the resources connected to the distribution system to contribute to congestion management at the distribution level. The French demonstrator focuses on the interactions between the TSO and the DSO established due to the already existing market architecture. One of the activities of the OneNet French demonstrator, the System for traceability of Renewable Activations (STAR), aims to track the activation of power generation curtailments, while the Tunnel of Warranty, aims to ensure that the resource activation in one system operator's network does not negatively affect other system operator's network. In the context of the present deliverable, Spain is of interest since the DSO market-based coordination is explored, while the Portuguese and French demonstrator activity focus on the technical-based TSO-DSO coordination required based on new and existing markets.

4.1.4 Eastern Cluster

The Eastern cluster comprises four demonstrator countries: Slovenia, Czech Republic, Poland, and Hungary. The Eastern cluster develops and extends capabilities of existing flexibility market platforms for TSO and DSO system services. The Polish demonstrator focuses on the market-based TSO-DSO coordination while the Slovenian, Hungarian, and Czech demonstrators focus mainly on the DSO coordination. The Slovenian demonstrator addresses several use-cases regarding using the resources connected at the distribution level to defer and avoid grid reinforcements; hence, an interoperable marketplace for flexibility enablement, the optimisation of ancillary services procurement, and TSO-DSO coordination is developed. Similarly, the demonstrator in the Czech Republic focuses on creating a new market platform for non-frequency services and defining those services as standard products. The Hungarian demonstrator investigates P and Q control for DSO congestion management, voltage control, and TSO-DSO coordination through information exchange. The Polish demonstrator has as the primary objective to enable the resources connected to the distribution level to support the system operation of both DSO and TSO. According to market-based coordination, a digital platform to procure the services for balancing, congestion management, and voltage control is developed and tested. All these demonstrators include the definition of a market model, which will be addressed and explained in detail in section 4.2.

4.2 Re-clustering the OneNet demos according to the theoretical market framework

Within each of the OneNet clusters, the demonstrators propose different designs for procuring system services that will be tested. The OneNet demonstrators are re-clustered into three main clusters to similar group characteristics regarding the type of coordination tested.

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The exploitation of third-party resources in power system operation involves at least two power system actors; hence, it is fundamental to coordinate[29] the parties involved. Therefore, in the context of system service procurement, at least a two-sided coordination between the power system actors is observed. However, more complex coordination schemes are required if more than two actors are part of the process of flexibility provision (e.g., it is the case in which the TSO uses flexibility resources connected to the distribution system). Regardless of the number of actors involved, the coordination for the procurement of system service can be considered market-based or technical-based. Market-based coordination describes the cases in which a market architecture coordinates the actors involved. The technical-based coordination describes the cases in which the actors interact directly by exchanging information and request for operating actions.

The OneNet demonstrators aim to contribute to coordinating the parties involved in the system service procurement and provision. In this deliverable, the analysis of the OneNet demonstrators is based on the part of the coordination chain TSO-DSO-FSP of interest for the demonstrator activities and the coordination scheme. Therefore, three clusters are defined to re-classify the OneNet demonstrators: TSO-DSO marked-based coordination, DSO market-based coordination, TSO-DSO technical-based coordination.

The demonstrators that belong to the market-based TSO-DSO coordination adopt a coordination scheme in which the TSO and the DSO are coordinated through a market (Figure 4-2). The flexibility is allocated between the system operators through market-based processes (e.g., bid forwarding, priority in bid selection). Thus, in the market-based TSO-DSO coordination, the market architecture for procuring flexibility is in-between the two system operators.

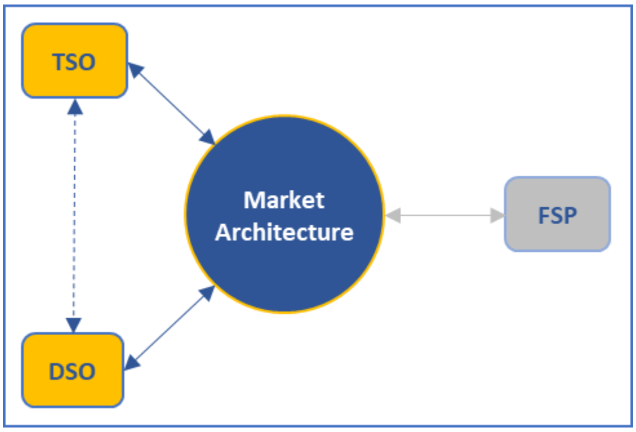

Figure 4-2. Scheme of the market-based TSO-DSO coordination

The OneNet demonstrators that belong to the DSO market-based coordination category focus on the mechanism to procure system services from FSPs to solve local needs. The market-based DSO coordination

[29] Coordination is considered with its broad meaning, the act of making all the people involved in a plan or activity work together in an organized way [42].

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concerns the adoption of market practices to allow the DSO to procure the system services from the FSPs (Figure 4-3). To test the DSO coordination, the demonstrators adopt a local market where the DSO has exclusive access to DERs. Even if the interaction with the TSO is not tested by the demonstrators belonging to this cluster, this interaction is considered in the theoretical design of the technical or market-based coordination.

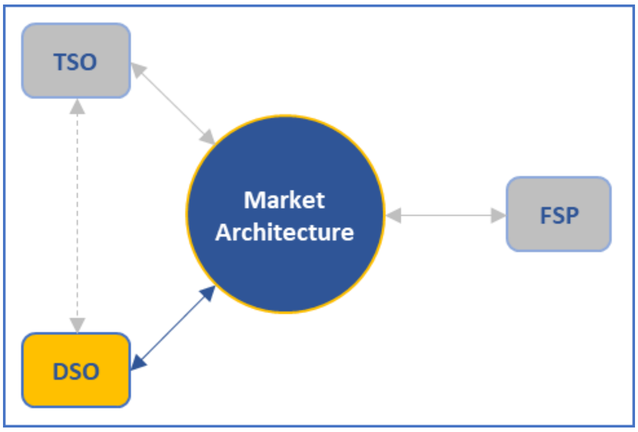

Figure 4-3. Scheme of the market-based DSO coordination

The demonstrators that belong to the technical-based TSO-DSO coordination adopt a coordination scheme in which the TSO and DSO directly interact by exchanging information and requests for operating actions (Figure 4-4). The flexibility is allocated between the system operators employing technical procedures (e.g., interaction between control centres and platforms). In the technical-based TSO-DSO coordination for procuring flexibility, a direct link between the two system operators exists. It is worth highlighting the technical-based coordination do not prevent the definition of a market architecture and the adoption of market-based coordination. The demonstrators adopting the technical-based coordination focus their activities on improving the technical aspects regarding the TSO-DSO coordination to allocate flexibility.

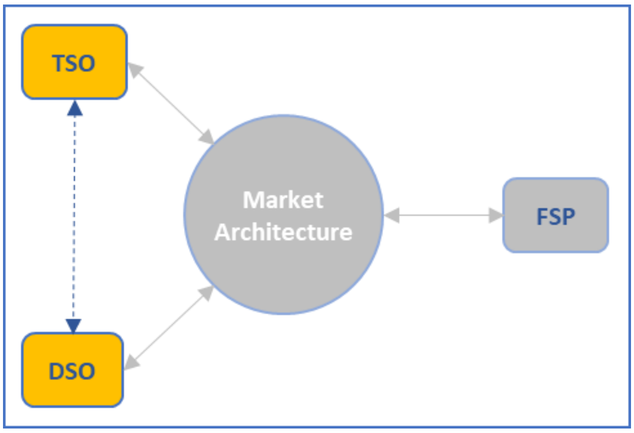

Figure 4-4. Scheme of the technical-based TSO-DSO coordination

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Considering the OneNet project activities, the demonstrators are re-clustered according to the type of coordination on which the activity focus. Table 4-1. provides the re-clustering of the One-Net demonstrators according to the type of TSO-DSO coordination adopted and the main focus of the demonstrators' activities.

Figure 4-5 and Table 4-1. provide the result of the re-clustering of the OneNet demonstrators, which analysis is presented in sections 4.2.1, 4.2.2, and 4.2.3. For the sake of clarity, the existing submarkets and new submarkets developed in the context of the OneNet project are distinguished. Finally, a cross-demonstrator comparison among the submarket level and at the coordination between the submarkets is presented.

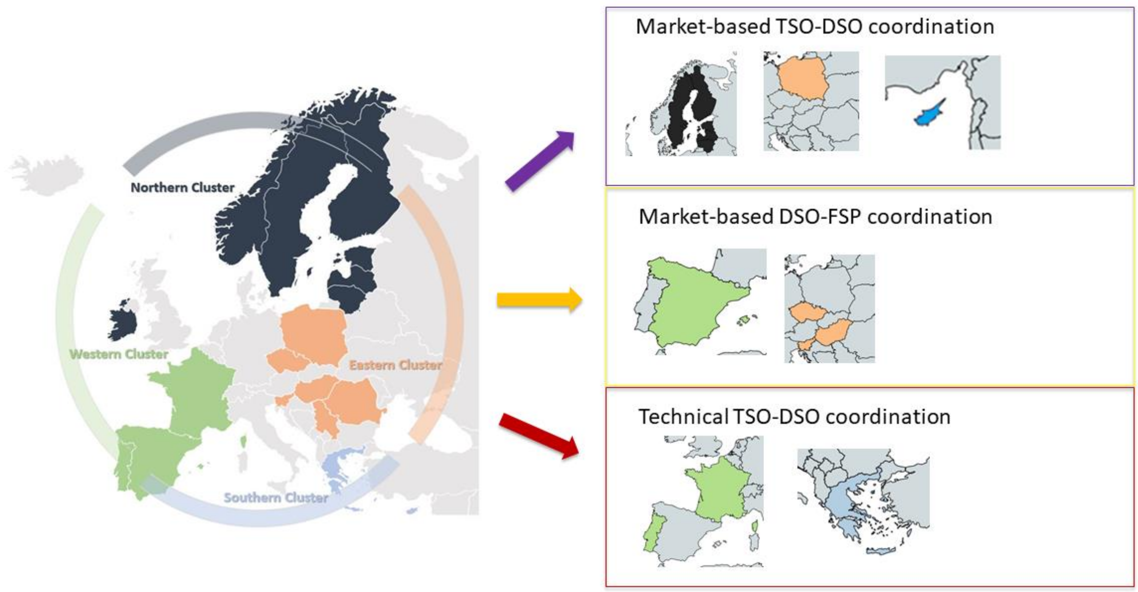

Figure 4-5. From geographical clustering to market design demonstrators' clustering

Table 4-1. Result of the re-clustering of the OneNet demonstrators

Market architecture	**Market-based TSO-DSO coordination**	**Market-based DSO coordination**	**Technical based TSO-DSO coordination**
OneNet Demonstrators	Cyprus; Poland; Northern cluster;	Spain; Slovenia; Hungary; Czech Republic	France; Portugal; Greece;

In this section, the explicit interactions between the submarkets that compose the market architecture are of interest. It is considered that an interaction exists between two submarkets if they are linked considering the forwarding of the bids or participation. The description of the whole market architecture model is obtained by composing all the interactions between the couples of submarkets.

A unified nomenclature is introduced for the description of the main submarkets that are analysed in this section. The structure of the exploited nomenclature is described in Table 4-2.

Table 4-2. Formalised nomenclature for naming the main submarkets

Element	**First**	**Second**	**Third**	**Fourth and fifth**
Meaning	Timing	FSP grid connection	Variable related to the product traded	Availability or activation of the flexibility to be provided
Options	LT (Long-Term)	T (Transmission)	P (Active power)	A (Availability)
	MT (Medium-Term)	D (Distribution)	Q (Reactive power)	E (Activation)
	ST (Short-Term)	TD (Transmission and Distribution)	PQ (Active and reactive power)	A-E (Availability and activation)
	WA (weeks ahead)			
	DA (Day-ahead)			
	ID (intraday)			
	NRT (Near-Real-Time)			
	RT (Real-Time)			
	ALL (All timeframes)			

An example of applying the nomenclature in Table 4-2 is ST-TD-P-A-E that describes a short-term submarket in which FSPs connected both at the distribution and the transmission system level participate. The electrical quantity exchanged is an active power in terms of availability and activation.

4.2.1 Market-based TSO-DSO coordination

This section focuses on the demonstrators developing and testing market frameworks and the corresponding interaction between TSOs and DSOs, as depicted in Figure 4-2. The OneNet demonstrators test either common markets or multilevel markets for procuring system services. The demonstrators described in this section adopt a market-based TSO-DSO coordination to allocate flexibility between the system operators.

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4.2.1.1 Cypriot Demonstrator

The Cypriot demonstrator, part of the southern cluster, is focused on a market architecture in which two new different submarkets coexist, incorporating both active and reactive power. This Cypriot OneNet demonstrator aims to:

- Provide an effective collaboration framework between TSO, DSO, Consumer, and Energy Markets;
- Develop the active balancing and congestion management platform to enable the active coordination of distribution grids;
- Allow aggregators and prosumers to provide active power, reactive power and power quality flexibility services to the power grid;
- Enable a higher penetration of RES without risking the stability and integrity of the system;
- Use the OneNet platform for facilitating the coordination between the TSO-DSO and the Market Operator.

The TSO and the DSO participate in the Cypriot market architecture to procure the products to address congestion management, frequency control, power quality, system adequacy, and voltage control.

In the Cypriot cluster, two new sub-markets have been proposed:

- Local TSO P submarket (ID-T-P-A);
- Local DSO P & Q submarket (ID-D-PQ-A and NRT-D-PQ-E);

The existing submarkets that are relevant for the scope of the demonstrator are:

- Day-ahead capacity submarket;
- Balancing reserve capacity submarket;
- Intraday energy submarket;
- Balancing Energy submarket.

Figure 4-6 provides an overview of the market architecture of the OneNet Cypriot demonstrator. The detailed description of the market architectures of the Cypriot demonstrator according to the theoretical market framework presented in section 3 is available in Table 4-3 for the Local DSO P & Q submarket. Table 4-4 for TSO exclusive submarkets, and Table 4-5, Table 4-6 for describing the interaction among the submarkets that compose the Cypriot market architecture.

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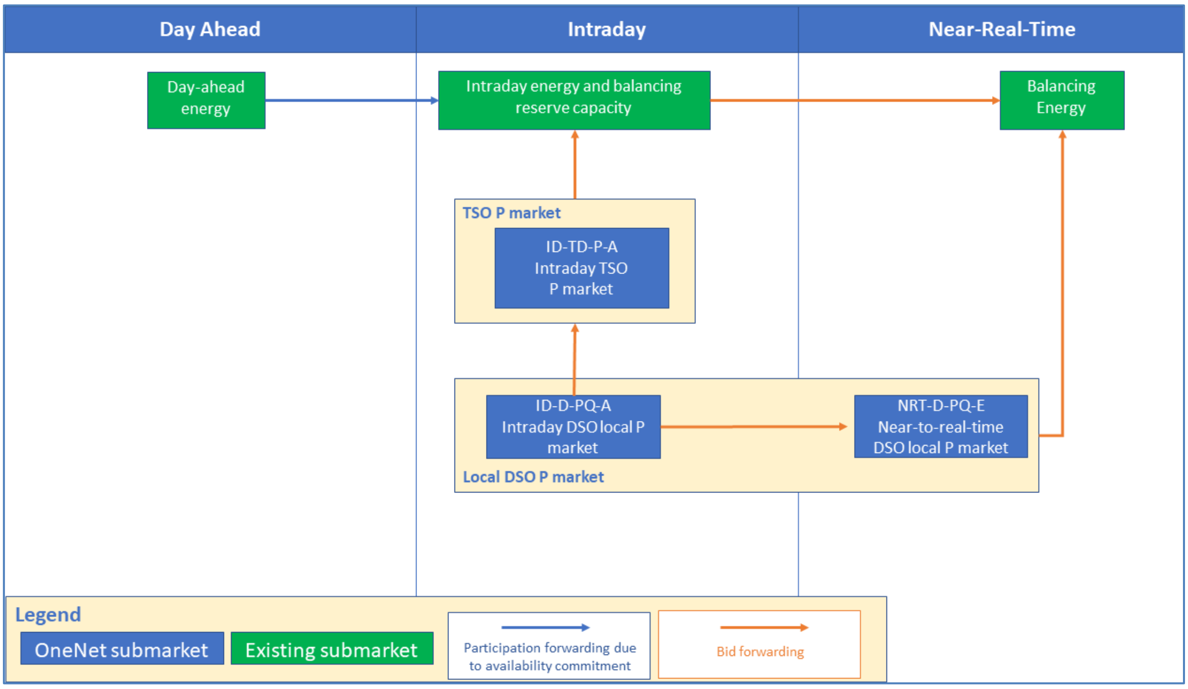

Figure 4-6. Overview of the Cypriot market architecture

As shown in Figure 4-6, the market architecture of the OneNet Cypriot demonstrator is composed of 2 submarkets: Local DSO P&Q (ID-D-PQ-A, NRT-D-PQ-E) and TSO P (ID-TD-P-A). The 2 submarkets both adopt the auction mechanism, and will exclusively be used by the DSO and TSO, respectively. As the name implies, the Local DSO P&Q and TSO P submarkets will be used for trading active and reactive power products for frequency and voltage control, congestion management, power quality, and system adequacy need. Therefore, the submarkets designed by the Cypriot demonstrator are service-agnostic.

The market-based TSO-DSO coordination is addressed in the Cypriot demonstrator through the designed, developed, and tested OneNet coordination platform. The procured products in the ID-TD-P-A submarket are known through the OneNet platform from the Local DSO PQ submarket. These products are pre-evaluated by the DSO based on the grid constraints. It is envisioned that the bids forwarded from the Local DSO PQ submarket to the TSO submarkets are aggregated considering the location of the market participants (i.e. the transmission substation that to which are connected). The ID-TD-P-A mainly considers frequency support products that are procured based on availability. The products coming from the FSPs connected at the distribution level are pre-evaluated by the DSO based on the grid constraints as the qualified products procured from the Local DSO PQ submarket. The received availability bids are first aggregated based on the location of the market participants (according to the transmission substation that they are connected to) and then forwarded to the TSO P market. The bids are formally forwarded from the ID-TD-P-A submarket to Intraday energy and balancing reserve capacity. The FSP associated with the availability bids cleared in the Intraday submarket (ID-D-PQ-A) will be obliged to participate in the near real-time submarket (NRT-D-PQ-E) to activate the related products.

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The market architecture for TSO-DSO coordination of the Cypriot demonstrator is a multilevel market model in which the DSO has the priority in the allocation of flexibility, as defined in Table 2-10.

4.2.1.2 Polish Demonstrator

The Polish demonstrator has the objective to deliver system services provided by resources connected to the DSO network. These services will be used for balancing, congestion management and voltage regulation. In addition, the flexibility services will be procured and activated to deliver services both for TSOs (balancing) and DSOs (congestion management and voltage regulation).

In the Polish cluster, one new sub-market has been proposed:

- Flexibility Submarket

One existing market has been considered with introduced changes:

- Integrated Balancing

The existing submarkets that are relevant for the scope of the demonstrator are:

- Day-ahead energy
- Intraday energy

Figure 4-7 provides an overview of the market architecture of the OneNet Polish demonstrator. In addition, the detailed description of the market architecture of the Polish demonstrator according to the theoretical market framework presented in section 3 is available in Table 4-3 for the Flexibility submarket, Table 4-4 for Integrating Balancing submarkets, and Table 4-5, Table 4-6 for the description of the interaction among the submarkets that compose the Polish market architecture.

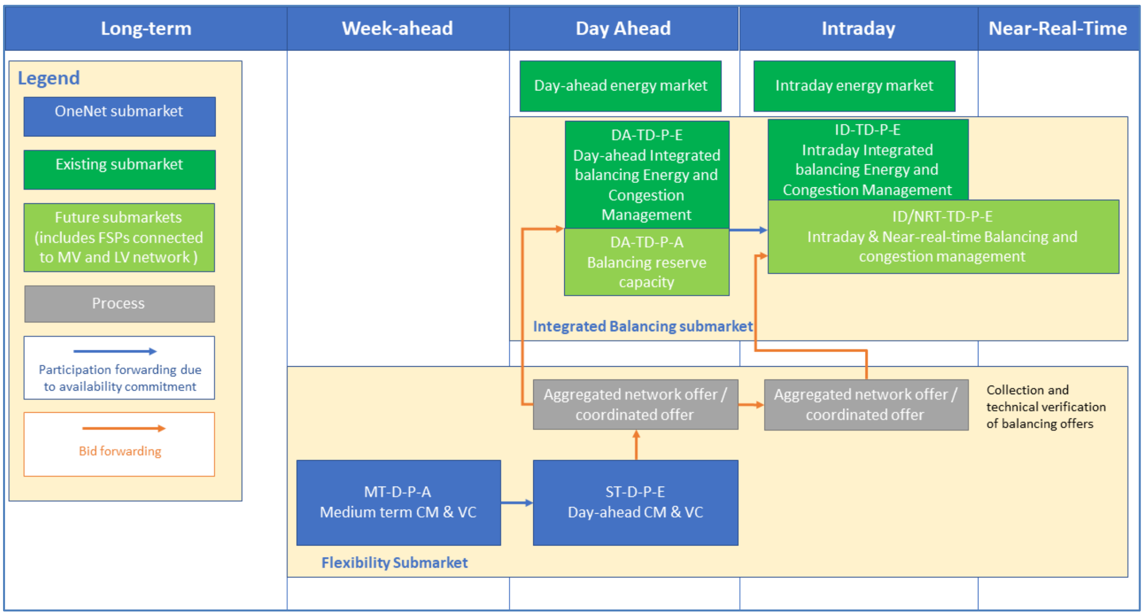

Figure 4-7. Overview of the Polish market architecture

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The Polish market comprises two main submarkets: Flexibility and Integrated Balancing. The two submarkets both exploit the auction procurement mechanisms. In the case of Integrated Balancing, it is a centralised continuous auction. Besides defining new submarkets and exploring the interaction with the existing markets, this demonstrator also adapts some of the existing markets. In this case, the balancing reserve capacity and balancing energy market will work as they do right now, although with the usual HV resources and integrating DER from the MV and LV networks. In the OneNet demonstrator, the resources connected to the MV and LV networks will be used only for balancing on the Integrated Balancing market; hence, these resources will be not exploited by the TSO to solve other system needs. The bids included in the Integrated Balancing submarket are:

a. Forwarded bids from the Flexibility submarket (ST-D-P-E)

b. New bids from FSPs connected at the distribution level that did not participate in the Flexibility submarket (ST-D-P-E). In case the above bids are compliant with balancing requirements they are aggregated to provide an aggregated offer.

c. New bids addressed to the Integrated Balancing submarket which standalone compliant with the balancing requirements

Regarding points *a.* and *b.*, the aggregation of the network offers to be submitted to the Integrate Balancing submarket considers the DSO network constraints. Therefore, the procurements of the Integrated balancing will not endanger the DSO grid. The FSP bids are aggregated in terms of their assignment to the TSO-DSO coupling points. The purpose of this aggregation is to ensure that the security of the distribution grid is not endangered and maximizing the volume of the aggregated offer.

The Integrated Balancing Market currently uses resources connected to the 110 kV network, which is coordinated by the TSO even if the DSO owns it. In this sense, in the Polish demonstrator, the coordinated 110 kV network is treated as the TSO network.

Inside the Flexibility Submarket, the Medium-term CM & VC (MT-D-P-A) will trade active power availability products that will later be activated in the Day-ahead CM & VC submarket (ST-D-P-E). As described, the unaccepted flexibility bids are aggregated and forward to the Integrated balancing submarket if they comply with the balancing market requirement. If not, the bids are rejected. The adapted Integrated Balancing submarket is formed by the Day-ahead integrated balancing energy and congestion management with balancing reserve capacity (DA-TD-P-A) and the Intraday integrated balancing energy and TSO congestion management with intraday and near real-time balancing and congestion management (ID-TD-P-E). Although these markets represent the integrated balancing market with TSO congestion management, the TSO only uses resources connected to the EHV and HV networks for congestion management.

The process blocks (in grey in Figure 4-7), represent the aggregation of a network offer to be submitted to the TSO markets. The aggregation is made through the use of the flexibility platform both in day-ahead and intraday. The aggregated bid to be forwarded depends on the forecasted needs from the DSO and TSO and type

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of products available at that time since the activation of DERs do not have to endanger the operation of the DSO network by violating the distribution network constraints. The aggregated network offer creates an equivalent balancing offer in the TSO-DSO coupling point. This offer includes all the FSPs in that DSO network and it is aggregated respecting the DSO network restrictions. Therefore, the range of the aggregated network offer already ensures that the DSO network is secure. Therefore, the DSO has priority of access to DER-FSPs. The Integrated balancing market cannot procure flexibility from DERs that can be dangerous for the DSO network. The aggregation practice proposed in the Polish demonstrator integrate the DERs in a relevant offer able to be forwarded to the Integrated Balancing submarket. The participation of DERs in the submarkets is optional for DERs and mandatory for central dispatched resources. The participation is also mandatory for DERs that were awarded balancing capacity.

The market architecture for TSO-DSO coordination of the Polish demonstrator is a multilevel market model, as defined in Table 2-10.

4.2.1.3 Northern Cluster demonstrator

The OneNet Northern cluster demonstrator envisions the definition of a market architecture that applies to all the demonstrators in the belonging countries. Therefore, all the countries involved in the Northern demonstrator are to implement the same market architecture, the countries interested in the development of the demonstrators are Finland, Estonia, Latvia, and Lithuania. The market architecture of the Northern demo includes the design of new markets for flexibility procurement.

In the northern cluster, the four main new sub-markets that have been proposed follow:

- Long-term submarket (P and Q availability and activation submarkets);
- Short-term submarket (P availability submarket and P activation submarket);
- Near-Real-Time P submarket (P activation submarket);
- Near-Real-Time Q submarket (Q activation submarket).

The existing submarket that is relevant for the scope of the demonstrator is the intraday energy market.

Figure 4-8 depicts an overview of the Northern cluster demonstrator market architecture. All the submarkets defined in the Northern cluster demonstrator are centralized markets. Therefore, there are not predefined boundaries for the bidding zones. However, all the bids could be provided with the locational attribute. Then, the interested SO can select the relevant bids according to the locational attribute for addressing local needs.

The Long-Term submarkets are linked to the Short-Term submarkets, but the attributes defining the link are set each time the Long-Term submarket is closed. In the Long-Term submarkets, availability is exchanged, normally, but not necessarily. The product traded could also be about the activation of flexibility.

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The detailed description of the market architecture of the Northern cluster demonstrator according to the theoretical market framework presented in section 3 is available in Table 4-7 for the Common TSO/DSO market architecture and Table 4-8 for the description of the interaction among the submarkets that compose the Northern cluster market architecture.

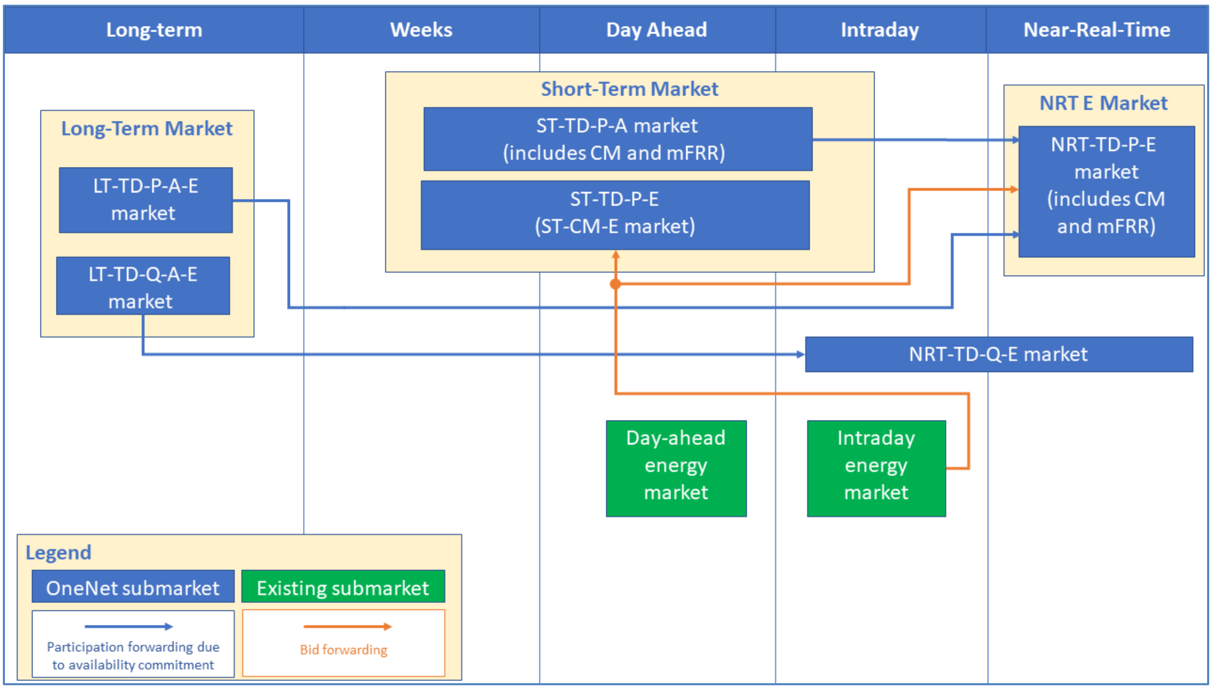

Figure 4-8. Overview of the Northern cluster demonstrator Market Architecture

In the long-term submarket developed by the OneNet Northern cluster demonstrator, two submarkets are included:

- Long-Term active power availability and activation submarket (LT-TD-P-A-E submarket)
- Long-Term reactive power availability and activation submarket (LT-TD-Q-A-E submarket)

In both submarkets, the system operators (TSO and DSO) can procure flexibility from FSPs. The flexibility is in terms of active and reactive power availability. The two long-term submarkets are service agnostic; however, if the bids are provided with locational information, the relevant system operator can activate the corresponding flexibility to solve local needs. The Long-Term active power submarket (LT-TD-P-A submarket) represents a mechanism in which the TSO and DSO procure active power availability and/or activation to provide flexibility from FSPs connected both at the transmission and the distribution system level. In this market, availability and/or activation is procured and remunerated. The Long-Term reactive power submarket (LT-TD-Q-A-E market) is also part of the long-term submarkets for flexibility procurement. It represents a mechanism in which the TSO and DSO procure reactive power availability and/or activation to provide flexibility from FSPs connected both at the transmission and the distribution system level. In this market, availability and/or activation is procured and remunerated.

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In the short-term submarket developed by the OneNet Northern cluster demonstrator, two submarkets are included:

- Short-Term active power availability submarket (ST-TD-P-A submarket);
- Short-Term congestion management activation submarket (ST-TD-P-E submarket).

In both submarkets, the system operators (TSO and DSO) can procure flexibility from FSPs that are connected both at the transmission and the distribution system level for active power availability (ST-TD-P-A sub-market) and activation (in ST-TD-P-E sub-market). The first of the two short-term submarkets is service agnostic while the other is dedicated to congestion management; if the bids are provided with locational information, the relevant system operator can employ the corresponding flexibility to address local needs.

The Near-Real-Time active power activation submarket (NRT-TD-P-E Market) developed by the OneNet Northern cluster demonstrator comprises only one submarket where a single product for frequency (mFRR) and congestion management is traded. In this submarket, the system operators (TSO and DSO) can procure flexibility from FSPs in terms of active power activation. The short-term submarket is service agnostic; if the bids are provided with locational information, the relevant system operator can employ the corresponding flexibility to address local needs.

In the Near-Real-Time reactive power activation submarket (NRT-TD-Q-E market) developed by the OneNet Northern cluster demonstrator, the system operators (TSO and DSO) can procure flexibility from FSPs in terms of reactive power activation. These FSPs can be connected both at the transmission and the distribution system level. This submarket is service agnostic; if the bids are provided with locational information, the relevant system operator can employ the corresponding flexibility to address local needs. The TSO/DSO coordination platform can check those bids and block the TSO activation of the offers that create problems to the operation of the DSO network. As an outcome, the bids that can create problems to the DSO grid cannot be used.

In the Northern cluster demonstrator, the Long-Term P availability submarket (LT-TD-P-A-E market) interacts with the near-real-time P activation submarket (NRT-TD-P-E market). Similarly, the long-term market for reactive power availability (LT-TD-Q-A-E market) interacts with the near-real-time reactive power activation submarket (NRT-TD-Q-E market). These explicit links concern the participation forwarding from the previous market to the following ones due to the established availability commitment. Moreover, in the Northern cluster demonstrator, an explicit link exists between the intraday energy market and the short term and near-real-time active power activation submarkets (ST-TD-P-E market and NRT-TD-P-E). This interaction involves bid forwarding. Thus, the unscheduled intraday bids could be used before the gate-closure in short term markets, while the leftovers could also be used in the near-real-time markets.

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The side effects of activating the resources are evaluated through a grid impact assessment as central activity of grid qualification process to avoid congestions by setting restrictions on the activation of flexibilities which would cause congestion in any grids.

4.2.1.4 Analysis of the market-based TSO-DSO coordination proposed by the OneNet demonstrators

This section analyses the different and common aspects of the previously presented markets by mapping these according to the theoretical market framework presented in section 3. To simplify the analysis of the market architecture, the OneNet demonstrators belonging to the market-based TSO-DSO coordination category are further classified according to the identified structure of the market architecture:

- Multilayer TSO/DSO (Cyprus, Poland)
- Common TSO/DSO (Northern cluster)

Two layers of submarkets form the multilevel TSO/DSO market architecture. One layer is dedicated to the TSO as a buyer, while the other layer has the DSO as the only buyer. The two layers communicate, allowing the TSO to procure services from DERs by formalising bid forwarding from the DSO layer to the TSO layer submarkets. The bids shared between the TSO and the DSO layer can be aggregated considering the operational constraints posed by the distribution network interconnecting the FSP and the TSO. The detailed description of the DSO layer of the Cypriot and Polish demonstrator is available in Table 4-3, while the TSO layer is described in Table 4-4. The interaction between the submarkets belonging to the two layers is described in Table 4-5, while Table 4-6 describe the interaction existing among the submarkets belonging to the same layer.

The common TSO/DSO market architecture, like the one designed and tested in the Northern cluster, is characterised by a unique layer formed by several submarkets in which both the TSO and the DSO are simultaneously involved as buyers. In common DSO/TSO submarkets, there is no explicit separation among the sets of FSPs that can be accessed by the different system operators that need to procure system services. Thus, the common DSO/TSO submarkets define a unique marketplace in which the TSOs and DSOs coordinate to procure flexibility provided by the same set of FSPs. Table 4-7 presents the theoretical market framework presented in section 3, the common market architecture designed by the Northern cluster. Table 4-8 describe the correlation existing among the submarkets of the Northern cluster market architecture.

As pointed out in Table 4-3 and Table 4-4, the multilayer TSO-DSO market-based architectures proposed by the OneNet demonstrators cover the medium and short-time timeframe for the procurement of system services from FSPs. In fact, the submarkets that compose the OneNet multilayer TSO-DSO market-based architectures range from week-ahead (Poland, MT-D-P-A) to near-real-time (Cyprus, NRT-D-PQ-E). The common TSO-DSO market-based architecture proposed by the Northern cluster OneNet demonstrators covers all the timeframes

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concerned by the system service procurement, from the long-term to the near-real-time, for active and reactive power (Table 4-7).

Multilayer TSO/DSO market-based coordination proposed by the Cypriot demonstrator and the common TSO/DSO market-based coordination proposed by the Northern cluster demonstrator allows procuring both the availability and activation active and reactive power products from the FSPs to address local and central system service needs. The multilayer TSO/DSO market-based coordination proposed by the Polish demonstrator is focused on the procurement of availability and activation of active power products from the FSPs. All the demonstrators implementing the TSO/DSO market-based coordination consider an auction submarket type. The uniform pay-as-cleared remuneration scheme is adopted by all demonstrators described in this section, the Northern cluster also adopts the pay-as-bid remuneration scheme for short-term submarkets. An IMO plays the role of the market operator in the Cypriot demonstrator.

In contrast, in the Polish demonstrator, the TSO and the DSO are the market operators of the respective submarkets. In the Northern cluster demonstrator, the TSO, the DSO, and an IMO can play the role of the market operator. While TSO and DSO define the flexibility products and launch calls for tender, the market operator plays the role of collecting the bids and formal matching bids and offers (actual optimisation is the task of the Optimisation Operator). If independent market operators are available to do these tasks, there is no need for TSOs and DSOs to take this role. However, in case IMOs are not providing this service, then system operators need to assume the role of MO. In all the demonstrators described in this section, the TSO has access to the flexibility that the DERs can offer. The Multilayer TSO/DSO market-based coordination enables indirect access to DERs since the FSP bids are aggregated before being available for the TSO. In the Northern cluster that implements a common TSO/DSO market-based coordination, the TSO directly accesses the FSP bids from DERs.

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Table 4-3. DSO exclusive submarket comparison (for the multilayer market architecture)

Feature	Attribute	Cyprus	Poland
Number of submarkets	Number of submarkets	2 a. ID-D-PQ-A b. NRT-D-PQ-E	1 a. MT-D-P-A, b. ST-D-P-E
Submarket dimension	Gate Opening Time (GOT)	a. Intraday a. Near-to-real-time	a. Week(s)-ahead, a. Day-ahead
	Timing of the submarket clearing (GTC)	b. Intraday c. Near-to-real-time	b. Week(s)-ahead, c. Day-ahead
	Sub-market type	Auction market	Auction Market
Products and services	Service	Congestion management; Power Quality; Voltage Control	Congestion Management, Voltage Control
	Product procured	a. Active and reactive power availability b. Active and reactive power activation	a. Active power Availability b. Active power Activation
Location	Level of spatial granularity	Zones at distribution level - Several substations, Zones at distribution level - A substation	Zones at distribution level - A substation, A Feeder
	Responsible System Operator	DSO	DSO
	Voltage Level where resources are located	MV, LV	MV, LV
Roles and actors	Who is the buyer(s)	DSO	DSO
	Who is the seller(s)	FSP	FSP
	Who is the MO	IMO	DSO
	Participation in submarket	a. Optional b. Hybrid	a. Optional b. Hybrid
Remuneration scheme		Pay-as-bid	Pay-as-bid

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Procurement frequency		a. Daily, b. Intraday	Event-based
Remunerated product attribute	Availability; Activation	a. Active and reactive power Availability; b. Active and reactive power Activation	a. Active power Availability b. Active power Activation
Market clearing type	Discrete; Continuous	Discrete	Discrete
Methodology to represent the grid	A. Comprehensive grid data	X	
	B. Partial grid data		X
	C. Empirical rules		X
Timing of grid constraints inclusion (primary problem)	Definition of procurement areas		B, C
	Technical pre-qualification		B
	Procurement phase		B
	Monitoring and activation	A	B
	Measurement, control of activation		C
	Settlement		C
Sub-market clearing objective	Minimisation of cost	X	X
	Maximisation of social welfare		X
Allocation principle of flexibility	System operators order (for the procurement of flexibility within a submarket)	Priority for DSO	Priority for DSO

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Table 4-4. TSO exclusive submarket comparison (for the multilayer market architecture)

Feature	Attribute	Cyprus	Poland	Poland
Number of submarkets	Number of submarkets	1 a. ID-TD-P-A	2 a. DA-TD-P-E, b. DA-TD-P-A	2 a. ID-TD-P-E, b. ID/NRT-TD-P-A
Submarket dimension	Gate Opening Time (GOT)	a. Intraday	a. Day-ahead b. Day-ahead	a. Intraday b. Intraday
	Timing of the submarket clearing (GTC)	a. Intraday	a. Day-ahead b. Day-ahead	a. Intraday b. Near-Real-Time
	Sub-market type	Auction Market	Auction Market	Auction Market
Products and services	Service	Frequency Control, Congestion management, System adequacy	a. Congestion management, b. Frequency Control	a. Frequency Control b. Congestion management,
	Product procured	Active power Availability	a. Active power Activation b. Active power Availability	a. Active power Activation b. Active power Availability
Location	Level of spatial granularity	National, Zones at transmission level	National, Nodes in transmission grid	Zones National, Nodes in transmission grid
	Responsible System Operator	TSO	TSO	TSO
	Voltage Level where resources are located	HV, MV, LV	HV, MV (only for balancing), LV (only for balancing)	HV, MV (only for balancing), LV (only for balancing)
Roles and actors	Who is the buyer(s)	TSO	TSO	TSO
	Who is the seller(s)	FSP	FSP	FSP
	Who is the MO	IMO	TSO	TSO
	Participation in submarket	Optional	Hybrid	Hybrid

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Remuneration scheme		Uniform pay-as-clear	Uniform pay-as-clear	Uniform pay-as-clear
Procurement frequency		a. Intraday	a. Daily; b. Intraday	a. Daily; b. Intraday
Remunerated product attribute	Availability; Activation	Active power Availability	a. Active power Activation b. Active power Availability	a. Active power Activation b. Active power Availability
Market clearing type	Discrete; Continuous	Discrete	Discrete	Continuous
Methodology to represent the grid	A. Comprehensive grid data	X		
	B. Partial grid data		X	X
	C. Empirical rules		X	X
Timing of grid constraints inclusion (primary problem)	Definition of procurement areas		B, C	B, C
	Technical pre-qualification		B	B
	Procurement phase		B	B
	Monitoring and activation	A	B	B
	Measurement, control of activation		C	C
	Settlement		C	C
Sub-market clearing objective	Minimisation of cost	X	X	X
	Maximisation of social welfare		X	X
Allocation principle of flexibility	System operators order (for the procurement of flexibility within a submarket)	Exclusivity for TSO	Exclusivity for TSO	Exclusivity for TSO
	TSO access to DERs	Yes	Yes	Yes

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As already described in sections 4.2.1.1 and 4.2.1.2, the multilayer TSO/DSO market-based architectures designed by the OneNet demonstrators are characterised by a TSO layer and a DSO layer that interact using forwarded bids. The bids forwarded by the DSO layer submarkets to the TSO layer submarkets are aggregated considering the operating constraints of the DSO network and the specific TSO/DSO interface corresponding to the FSPs connected at the distribution level. This market architecture provides priority to the DSO considering the allocation principle of flexibility. Table 4-5 provides the TSO and DSO submarket interaction description according to the theoretical market framework described in section 3.

The Cypriot demonstrator implements decentralised market optimisation since the DSO first qualify the FSP bids from DERs to be forwarded to the TSO market. The Polish demonstrator implements both a centralised and decentralised procurement since the FSP bids from DERs can be forwarded from the DSO layer or can be directly submitted to the TSO layer, in this case the DSO qualifies the FSP bids from DERs after that the TSO selected them. Hence, in all cases bid forwarding is conditional, except for the relationship between the ID-TD-P-A and the ID energy submarket of the Cypriot demonstrator since both are TSO submarkets. The multilayer TSO/DSO market-based architectures designed by the OneNet demonstrator show an independent optimisation strategy between parallel submarkets.

Table 4-6 provides the description of the interactions existing between submarkets belonging to the same layer considering the multilayer TSO/DSO market-based architectures designed by the OneNet demonstrators. Both cases include the commitment of the FSPs cleared in the availability submarket to participate in the corresponding activation submarket.

Table 4-5. Interactions between DSO and TSO submarkets for the multilayer market-based TSO/DSO coordination architectures

Feature	***Attribute***	***Options***	***Cyprus***	***Cyprus***	***Cyprus***	***Poland***
Linked submarkets			1. ID-D-PQ-A 2. ID-TD-P-A	1. ID-TD-P-A 2. ID energy	1. NRT-D-PQ-A-E 2. Balancing Energy	1. Flexibility 2. Integrated balancing
Market optimization		Centralised; Decentralised; Distributed	Decentralised	Decentralised	Decentralised	Decentralised
Submarkets optimisation strategy		Sequential; Simultaneous; Independent	Independent	Independent	Independent	Independent
Interaction descriptors	Forwarding of bids	Yes/No	Yes	Yes	Yes	Yes (only for balancing)
	Commitment to bid selection	Formal; Conditional	Conditional	Formal	Conditional	Conditional
Timeframe for coordination	Market phase for coordination between submarkets	Technical pre-qualification				X
		Procurement	X	X	X	X
		Monitoring and activation				
		Measurement				
		Control of activation				
		Settlement				
Allocation of flexibility			Priority for DSO	Not applicable	Priority for DSO	Priority for DSO

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Table 4-6. Interactions within the DSO and TSO exclusive submarkets for the multilayer market-based TSO/DSO coordination architectures

Feature	Attribute	Options	Cyprus	Poland
Linked submarkets			1. ID-D-PQ-A 2. NRT-D-PQ-E	1. MT-D-P-A-E 2. ST-D-P-A-E
Market optimization		Centralised; Decentralised; Distributed	Not applicable	Not applicable
Market optimisation strategy		Sequential; Simultaneous; Independent	Sequential	Sequential
Interaction descriptors	Forwarding of bids	Yes/No	No	No
	Commitment to bid selection	Formal; Conditional	Not Applicable	Not Applicable
Timeframe for coordination	Market phase for coordination between submarkets	Technical pre-qualification		
		Procurement	X	X
		Monitoring and activation		
		Measurement		
		Control of activation		
		Settlement		
Commitment to participate in the activation submarket (from submarket 1 to 2)			Yes	Yes

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Table 4-7. Description of the submarkets in the common TSO/DSO market-based coordination architectures

Feature	Attribute	Northern Cluster (P and Q Availability / Activation)	Northern Cluster (P Availability / Activation)	Northern Cluster (P and Q NRT activation)
Number of submarkets	Number of submarkets	2 a. LT-TD-P-A-E b. LT-TD-Q-A-E	2 a. ST-TD-P-A b. ST-TD-P-E	2 a. NRT-TD-P-E b. NRT-TD-Q-E
Submarket dimension	Gate Opening Time (GOT)	More than month ahead	From intraday to weeks ahead	Near-Real-Time
	Timing of the submarket clearing (GTC)	Month ahead	Intraday	Near-Real-Time
	Sub-market type	Auction market	Auction market	Auction market
Products and services	Service	Agnostic (Frequency control, voltage control, congestion management)	a. Agnostic (Freq. control, voltage control, congestion management) b. b. Congestion management	a. Agnostic b. (Voltage control)
	Product procured	a. Active power Availability b. Reactive power Availability c. Active power Activation d. Reactive power Activation	a. Active power Availability (includes mFRR capacity) b. Active power Activation	a. Active power Activation (includes mFRR energy) b. Reactive power activation
Location	Level of spatial granularity	National, Zones transmission, Distribution system. Centralised procurement.	National, Zones transmission, Distribution system. Centralised procurement.	National, Zones transmission, Distribution system. Centralised & Local procurement since locational information in the bids
	Responsible System Operator	TSO, DSO	TSO, DSO	TSO, DSO

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	Voltage Level where resources are located	HV, MV, LV	HV, MV, LV	HV, MV, LV
Roles and actors	Who is the buyer(s)	TSO in the future, DSO in the future	TSO in the future, DSO in the future	TSO (in the future for reactive power), DSO in the future
	Who is the seller(s)	FSP	FSP	FSP
	Who is the MO	DSO, TSO, IMO	DSO; TSO; IMO	DSO; TSO; IMO
	Participation in submarket	Optional	a. Optional b. Optional	Hybrid (mandatory in case FSP has been remunerated for availability)
Remuneration scheme		Uniform pay-as-cleared	a. Uniform pay-as-cleared b. Pay-as-bid	Uniform pay-as-cleared
Procurement frequency		More than monthly	Daily/weekly	Intraday
Remunerated product attribute	Availability; Activation	a. Active power Availability b. Reactive power Availability c. Active power activation d. Reactive power activation	a. Active power Availability b. Active Power Activation	a. Active power Activation b. Reactive Power Activation
Market clearing type	Discrete; Continuous	Discrete	Discrete	Discrete
Methodology to represent the grid	A. Comprehensive grid data	X	X	X
	B. Partial grid data	X	X	X
	C. Empirical rules	X	X	X
Timing of grid constraints inclusion (primary problem)	Definition of procurement areas			
	Technical pre-qualification	X	X	X
	Procurement phase	X	X	X

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	Monitoring and activation	X	X	X
	Measurement, control of activation			
	Settlement			
Sub-market clearing objective	Minimisation of cost			
	Maximisation of social welfare	X	X	X
Allocation principle of flexibility	System operators order (for the procurement of flexibility within a submarket)	None	None	None
	TSO access to DERs	Yes	Yes	Yes

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Table 4-8 provides the description of the interactions between the submarkets in the Common DSO/TSO market architecture. The Northern cluster demonstrator implements a centralised optimisation since the common TSO/DSO market architecture. Bid forwarding between linked submarket is formal, submarkets are sequentially optimised. Each submarket contains bids both from FSP at transmission and distribution level. If the locational information is included in the bid, it can be exploited to solve local needs. Both the TSO and the DSOs are the buyers for all the submarkets. Furthermore, in the Northern cluster demonstrator, availability and the corresponding activation submarkets include the commitment of the FSPs cleared in the availability submarket to participate in the corresponding activation submarket.

Table 4-8. Interactions between submarkets in the common TSO/DSO market-based coordination architectures

Feature	***Attribute***	***Options***	***Northern cluster***
Linked submarkets			1. ID energy markets 2. ST-TD-P-E, NRT-TD-P-E
Market optimization		Centralised; Decentralised; Distributed	Centralised
Submarkets optimisation strategy		Sequential; Simultaneous; Independent	Sequential
Interaction descriptors	Forwarding of bids	Yes/No	Yes
	Commitment to bid selection	Formal; Conditional	Formal Before ID gate closure, the bids submitted to ID market can be used by system operators to address congestion management (ST-TD-P-E). After ID gate closure the unused bids can be forwarded to NRT-TD-P-E market.
Timeframe for coordination	Market phase for coordination between submarkets	Technical pre-qualification	
		Procurement	X
		Monitoring and activation	X
		Measurement	
		Control of activation	
		Settlement	

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4.2.2 Market-based DSO coordination

The market-based DSO coordination describes the procurement mechanisms in which the flexibility from FSPs solves the local needs of the relevant system operator without affecting other areas. Therefore, both the need and the exploited resources belong to the same area. Moreover, the interaction based on the mechanism defined in Table 2-5. with other system operators operating in different or upstream network areas will depend on the specific market design. Therefore, in some cases, no interaction with other system operator is tested during the OneNet project. Potential interaction could be developed in the future for some demonstrators. Moreover, this deliverable focuses on the mechanism for procuring flexibility as can be described by the theoretical market framework proposed in section 3; therefore, the analysis of the interactions such as information exchange is out of the scope. Work packages 4, 5 and 6 of the OneNet project focus on the data exchange and the technical coordination among the parties involved in the flexibility procurement.

In the context of the OneNet project, four demonstrators concern the exploitation of local market architectures:

- Spain demonstrator;
- Czech Republic demonstrator;
- Slovenia demonstrator;
- Hungary demonstrator.

This section addresses the description of the four demonstrators according to the theoretical market framework presented in section 3. Table 4-9 contains the detailed description of the market architectures of the four demonstrators for the long-term submarkets, Table 4-10 for the short-term submarkets, and Table 4-11 for the links existing between the long-term and the short-term submarkets. The content of the tables reflects the current state of the activities of the demonstrators. However, some information is missing, and several choices still have to be made. Therefore, changes or additions may occur as the OneNet project progresses.

4.2.2.1 Spain Demonstrator

The OneNet Spanish demonstrator aims at unlocking the flexibility of the resources connected to the distribution system to contribute to congestion management at the distribution level. Local markets in which the DSO is the only buyer of the flexibility services, and the FSPs are the sellers, are tested. In the Spanish demonstrator cluster, two main submarkets are proposed:

- Long-term submarket (P availability and activation submarket, and a P availability submarket);
- Short-term submarket (day-ahead and real-time P activation submarket).

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The existing submarkets that are relevant for the scope of the demonstrator are:

- Day-ahead energy market
- Intraday energy market
- Common congestion management market
- Balancing energy market

Figure 4-9 provides an overview of the market architecture of the OneNet Spain demonstrator. All the new submarkets are decentralized markets and event-based. In the case of a need for system services, the DSO asks the IMO to open a call in a specific grid area to procure flexibility. The system service procured is active power flexibility. It is procured active power availability, activation, or both depending on the submarket considered. Table 4-9, Table 4-10, and Table 4-11 provide a detailed description of the market architectures of the Spanish demonstrator according to the theoretical market framework presented in section 3.

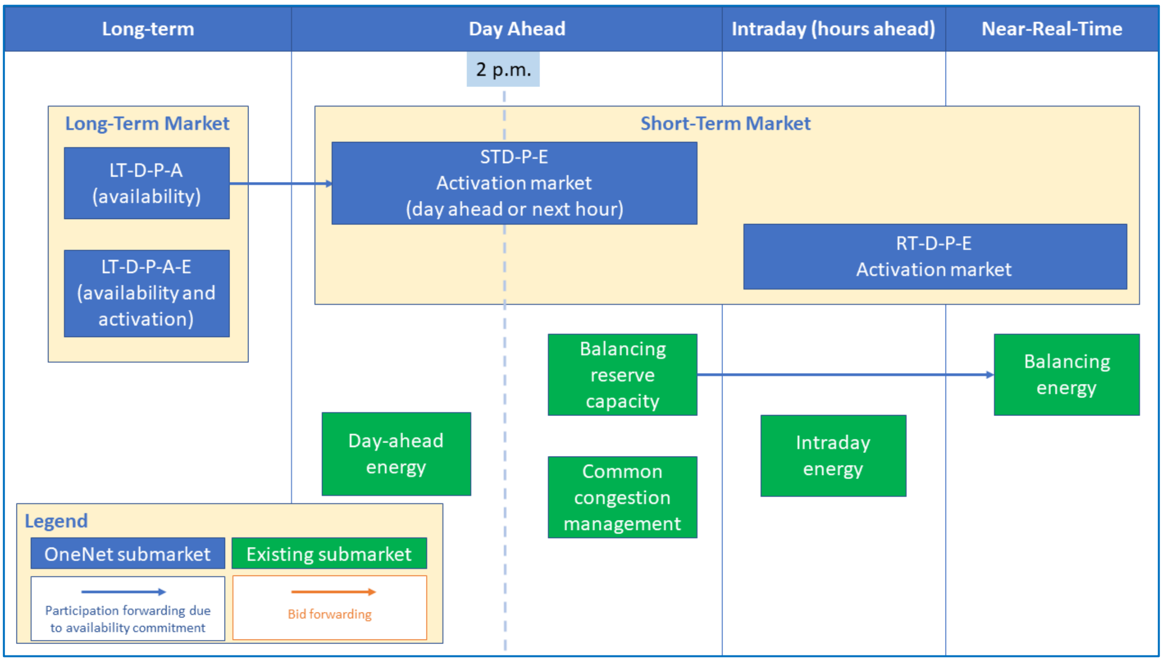

Figure 4-9. Overview of the Spanish demonstrator Market Architecture. LT-P: Long-term active power, ST-P: short-term active power.

In the long-term submarket developed by the OneNet Spanish demonstrator, are included:

a. Long-Term active power availability submarket (LT-P-A);
b. Long-Term active power availability and activation submarket (LT-P-A-E).

The Long-Term P availability (LT-P-A) submarket is part of the long-term submarkets for flexibility procurement. It represents a local mechanism in which the DSO procures active power flexibility in terms of availability from FSPs connected at the distribution system level. The FSPs belonging to the procurement area compete by submitting availability bids to the local auction marketplace. The Long-Term active power availability and activation submarket (LT-P-A-E) has a similar structure; however, the bids submitted by the FSPs include

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both the availability and the activation offer. In this market, the DSO procure both availability and activation. This market is designed for procuring flexibility services in all those cases in which the need for flexibility can be forecasted long in advance; hence, the activation of the FSPs can be scheduled long in advance with high reliability.

In the short-term submarket developed by the OneNet Spanish demonstrator, two are included:

a. Short-Term-P activation submarket (ST-P-E);
b. Real-Time P activation submarket (RT-P-E).

The Short-Term P activation submarket (ST-P-E) is part of the short-term submarkets for flexibility procurement. It represents a day-ahead local mechanism in which the DSO can procure active power flexibility from the FSPs connected at the distribution system level. In this market, active power activation is procured and remunerated; however, the submarket structure leaves open the possibility to remunerate also availability in some cases. The peculiarity of this submarket relies on the fact that it is composed of two different time procedures. If the market operator receives the request for flexibility before 2 p.m., the auction opens at 2 pm; otherwise, the auction opens at the next hour. Although all the FSPs in the relevant procurement area can participate in the related auction, the participation of the FSPs that have been cleared in the Long-Term active power availability submarket (LT-P-A) is mandatory. These FSPs can bid a different amount and price in the short-term submarket. However, the ST-P-E auction is characterised by a reserve price established by DSO (maximum price accepted by the algorithm in the auction process) that cannot be exceeded and is related to the long-term matching price.

The Real-Time P activation submarket (RT-P-E) is part of the short-term submarkets for flexibility procurement. It represents a local mechanism that occurs on the same day of the delivery in which the DSO procures active power flexibility from FSPs connected at the distribution system level. In this market, active power activation is procured and remunerated. Participation in the RT-P-E submarket is open to all qualified FSPs, and there is no link with the long-term submarkets (LT-P-A and LT-P-A-E).

In the Spanish demonstrator, only the Long-Term P availability submarket (LT-P-A) and Short-Term P activation submarket (ST-P-E) directly interact. This interaction is based on the fact that the FSPs cleared in the long-term availability market are obliged to participate in the short-term market. In any case, the FSPs can submit new bids and update the implicit activation bid.

4.2.2.2 Czech Republic Demonstrator

The Czech Republic demonstrator aims to create a new market platform for non-frequency services and define those services as a standard product, which can be offered by all actors at the distribution level (DER, BESS, and DSR) in line with a TSO-DSO-Consumers coordination scheme. The market platform developed by the Czech demonstrator define the term-period of the produce as one parameter dependent on the need for system service; therefore, with the aim to avoid the existence of parallel markets. The market platform developed by the Czech Republic demonstrator concerns only non-frequency services for the DSO, the TSO is not part of the market processes of the developed platform. The TSO-DSO coordination is addressed in the Czech demonstrator in terms of data exchange concerning grid availability. The data exchange TSO-DSO is integrated into the new platform proposed by the Czech demonstrator. Regarding the procurement of non-frequency grid services of interest for this document, there is not direct involvement for TSO, the TSO related services procurement is addressed through existing platform for balancing services. However, the platform designed and tested by the Czech demonstrator would also enable the TSO to procure services if needed.

In the Czech Republic demonstrator, the one main submarket proposed for the procurement of non-frequency DSO grid services:

- Local PQ submarket (ALL-D-PQ-A)

Evan if no interaction is developed and tested in the Czech OneNet demonstrator, the existing submarkets that are relevant for the description of the demonstrator are:

- Day-ahead energy market
- Intraday energy market
- Balancing reserve capacity
- Balancing energy market

All the new submarkets are decentralized markets; however, in this section, only the active power market is considered, since, within it, both the TSO and the DSO can procure flexibility from the same set of FSPs. Figure 4-10 provides an overview of the active power market architecture of the OneNet Czech Republic demonstrator. Table 4-9, Table 4-10, and Table 4-11 provide a detailed description of the market architectures of the Republic demonstrator according to the theoretical market framework presented in section 3.

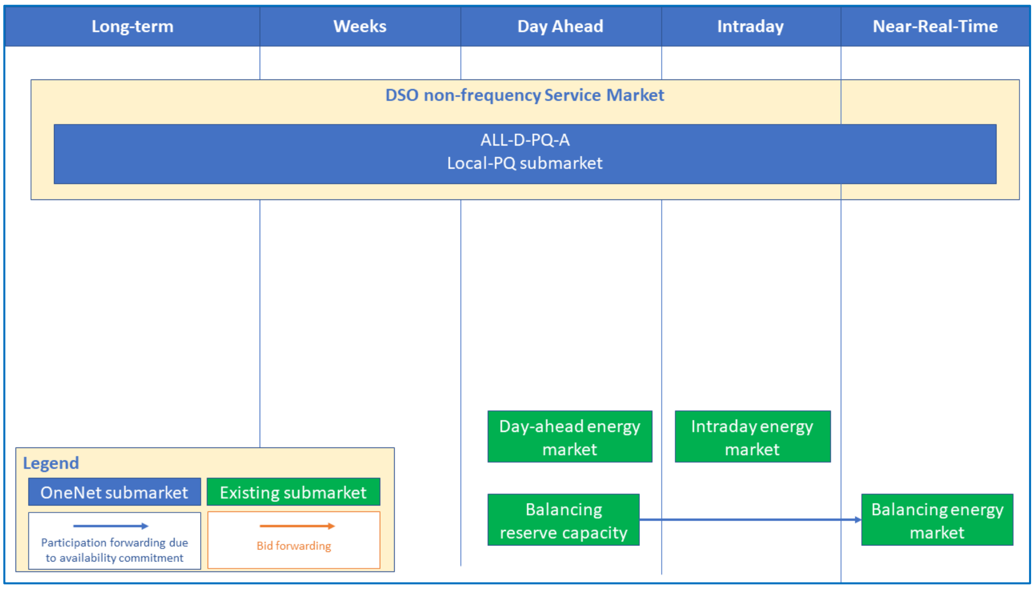

Figure 4-10. Overview of the market architecture of the Czech Republic demonstrator

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In the Local-PQ submarket (ALL-D-PQ-A) the DSO can procure non-frequency grid services from the FSPs connected at the distribution level. The non-frequency grid services procured are in terms of active and reactive power availability. Time term is a parameter for the procurement process, therefore, both long-term and short-term product are exchanged in the market platform. The main focus of the Czech demonstrator is on the design and test of the relevant IT market place, establish data exchange model, data protocols. The new platform will enable implementation of flexible market environment allowing interaction of multiple parties in order to create service price through an auction market. However, the developed market platform is flexible and different procurement mechanisms can be adopted for matching demand and offer.

4.2.2.3 Slovenia Demonstrator

The Slovenia demonstrator main focus is on the harmonisation of the EU wide system services for DSOs, the definition of an interoperable marketplace enabling FSPs to sell service to both DSOs and TSOs through a transparent and standardized system procedure, the optimization of the size of the procured system services by DSOs and TSOs, and the strategies to ensure non-contradicting service activation by DSOs and TSOs in real case scenarios (DSO-TSO coordination).

However, the TSO is not actively involved in the activity of the OneNet Slovenian demonstrator. The demonstrator strives to harmonise new DSO product(s) with TSO existing products and also design TSO-DSO data exchange model. Even though TSO-DSO data exchange will be designed and tested in the Slovenian OneNet demonstrator, TSO or DSO will not change their operation based on the data exchanged. The Slovenian demonstrator develops and tests the interoperable marketplace (platform) to be used to procure the DSO services developed in OneNet. This DSO platform is independent of the TSO marketplace platform for balancing services which is not considered of the OneNet project. The DSO marketplace platform designed by the Slovenian OneNet demonstrator focuses on local flexibility procurement. This novel local flexibility marketplace platform has the ambition of being the sole national flexibility marketplace for all FSP providers and buyers (DSO and TSO). The new flexibility marketplace platform will not replace the existing balancing IT infrastructure of TSO and DSOs but it will be integrated into existing TSO and DSO platforms. The integration of the existing with the novel platform for local flexibility would enable to manage all flexibility in “one place”. In this context, the OneNet demonstrator represents the cornerstone for the development of this long-term goal.

The Slovenian demonstrator consists of a locational flexibility market platform and several areas at low voltage level where network issues will be solved using flexibility sources provided by several types of FSPs (e.g. heat pumps, EVs).

In the Slovenian cluster, one new sub-market is proposed:

- Long-term submarket (seasonal local active power submarket).

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Alongside the local market for flexibility procurement, the Slovenian demonstrator will not demonstrate a TSO-DSO market-based coordination. Only TSO-DSO information exchange about the local trading will be performed. Based on implemented data-exchange, the Slovenian demonstrator will theoretically formalise and test the market-based coordination, transparent and standardized system procedures, optimization of the size of the procured system services, and the strategies to ensure non-contradicting service activation.

The existing submarkets that are relevant for the scope of the demonstrator are:

- Day-ahead energy market
- Intraday energy market
- Balancing reserve capacity
- Balancing energy market

Figure 4-11 provides an overview of the market architecture of the OneNet Slovenia demonstrator. The detailed description of the market architecture of the Slovenian demonstrator according to the theoretical market framework presented in section 3 is available in Table 4-9, Table 4-10, and Table 4-11.

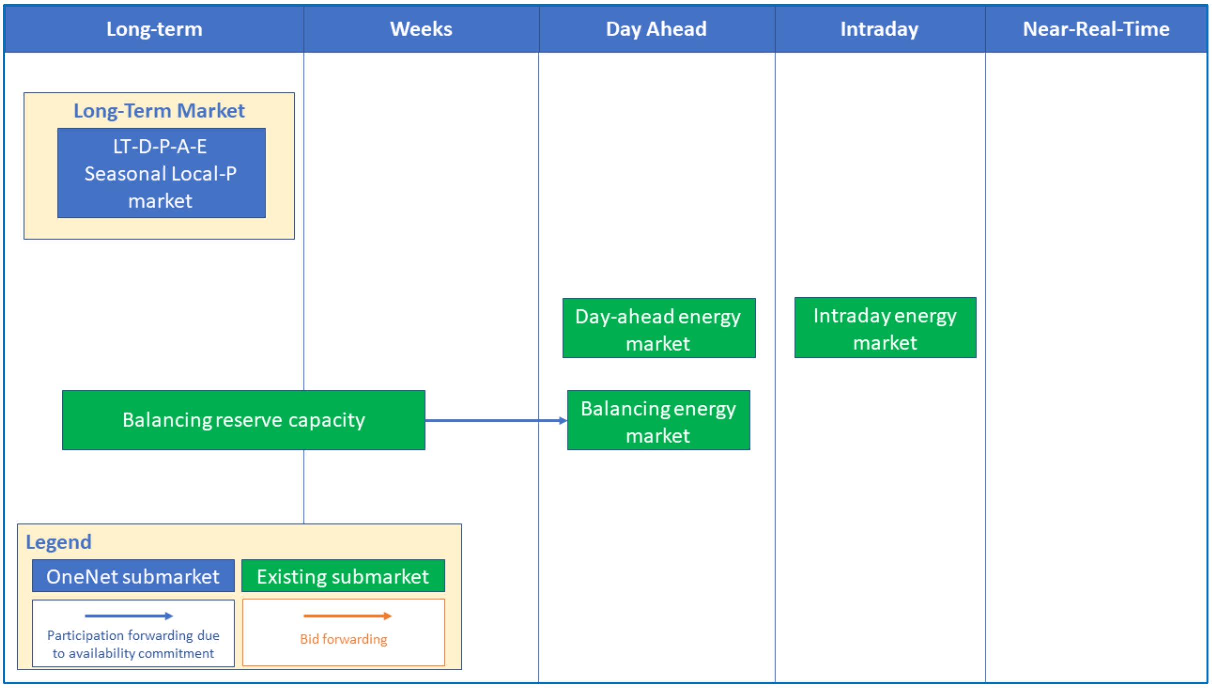

Figure 4-11. Overview of the market architecture of the Slovenia demonstrator

The long-term submarket (LT-P-A-E) developed by the OneNet Slovenia demonstrator allows the DSO to procure flexibility from local FSPs is in terms of active power availability and activation. The seasonal Local P availability submarket is characterized by an auction process in which the FSPs submit bids. Only the DSO market will be demonstrated in the OneNet project. The interactions with the Intraday Energy market, Balancing Reserve Capacity market and the Balancing Energy market will not be demonstrated, however, these

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interactions could be possible in the future. In the LT-P-A-E submarket, active power availability is negotiated between the DSO and the FSPs. The active power availability is in terms of a time window in which the FSPs could be activated manually or automatically by the DSO. The activation of the FSPs is remunerated according to the wholesale electricity prices (EUR/MWh), therefore, no explicit market mechanism is required to procure activation. The activation of each FSP cannot exceed the active power capacity agreed in the availability long-term submarket. The availability payment depends on the agreed active power capacity procured and the duration of the availability window (EUR/MW/h).

4.2.2.4 Hungarian Demonstrator

The Hungarian demonstrator is part of the Eastern cluster with the Czech Republic, Poland, and Slovenia. The Hungarian demonstrator aims to create functional extensions of the flexibility platform that regards:

- The definition of new potential standardized flexibility services
- The definition of the related products and grid prequalification processes
- The conceptualisation of location-based service activation
- The coordination of access to local and system-level services

The Hungarian demonstrator investigates the use of active and reactive products for voltage control and congestion management at the DSO level. The demonstrator will not overlap with existing markets. The market architecture developed by the Hungarian demo enables the DSO to acquire services from FSPs to cover voltage control and network congestion management needs. Figure 4-12 depicts that the Hungarian market contains long-term and short-term submarkets in which the DSO is the only buyer that procures active and reactive power or energy through an auction mechanism. The TSO is involved in the Hungarian demonstrator, however, the flexibility products tested within OneNet testing are especially specific to DSOs. Nevertheless, the connection to TSO operation is twofold:

- DSO connected resources are already participating (to some extent) in providing system balancing to the TSO.
- DSO activation of local flexibility can exacerbate TSO issues in HV grid management.

Therefore, the TSO-DSO coordination in the OneNet Hungarian demonstrator relates to information sharing, and the use of a tailored implementation of the traffic-light concept.

The detailed description of the market architectures of the Hungarian demonstrator according to the theoretical market framework presented in section 3 is available in Table 4-9 for the long-term submarkets, Table 4-10 for the short-term submarkets, and Table 4-11 for the links existing between the long-term and the short-term markets.

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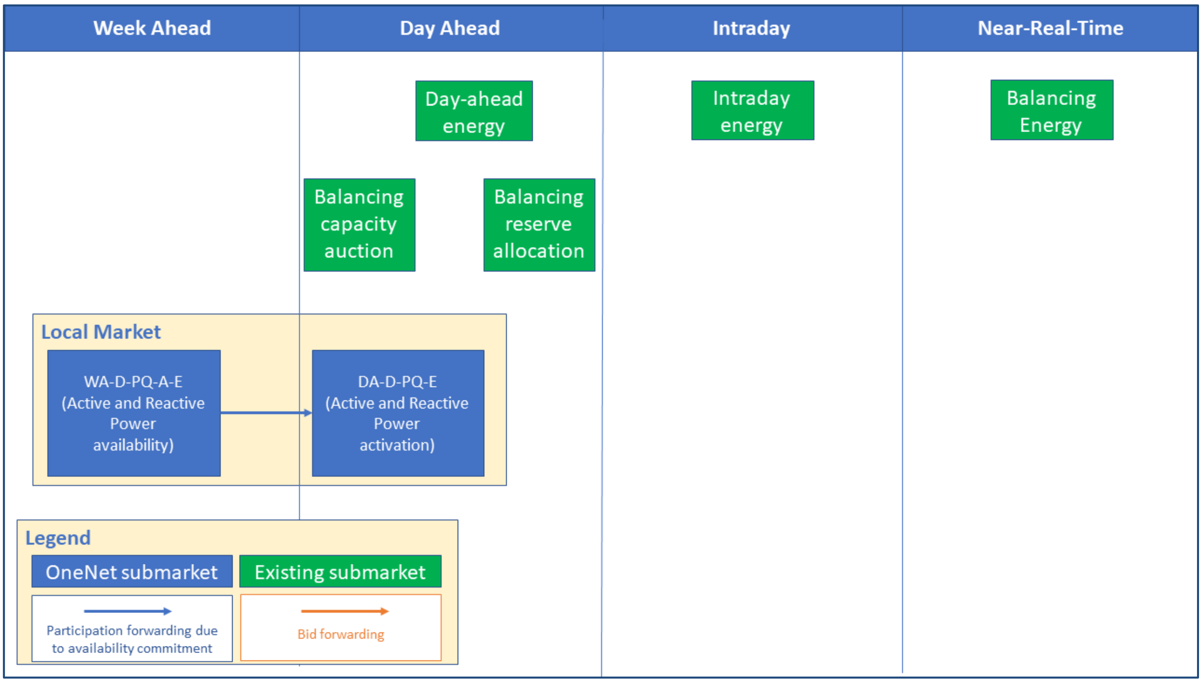

Figure 4-12. Overview of the Hungarian Market

As depicted in Figure 4-12, the Hungarian market architecture is composed of a local local-long term (WA-PQ-A) and a short-term submarket (DA-D-PQ-E) in which both active and reactive power products are exchanged. In the long-term local submarket (WA-D-PQ-A-E), the DSO procure flexibility (availability and/or activation) from FSPs to solve local needs. The availability procurement is planned weekly. In the short-term market (DA-D-PQ-E), the DSO procures active and reactive power day-ahead activation daily. Even if no interaction with other submarkets is demonstrated in the Hungarian demonstrator, theoretical connections can be drawn between the OneNet submarkets and the existing submarkets. The bids that are not accepted in the OneNet local market can be aggregated and forwarded to the TSO markets. In the Hungarian demonstrator, the Long-Term submarket (WA-PQ-A-E) and Short-Term submarket (DA-D-PQ-E) have an explicit interaction regarding the commitment to participate in the activation submarket. However, the FSPs cleared in the long-term availability market are not obliged to participate in the short-term market. However, the short-term activation market is also open to the participation of new FSPs (i.e. FSPs that have not been cleared in the long-term availability market).

4.2.2.5 Analysis of the market-based DSO coordination proposed by the OneNet demonstrators

In this section, the market-based DSO coordination architectures adopted in the OneNet demonstrators are analysed according to the theoretical market framework presented in section 3. The market-based DSO coordination architectures proposed by the OneNet demonstrators have been classified for the present analysis

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in long-term and short-term submarkets. It represents an appropriate classification due to the characteristics of the proposed market architectures. Long-term and short-term submarkets differ in terms of timing and product acquisition. Moreover, considering the different demonstrators, similarities exist within the short-term submarkets and the long-term submarkets. For the sake of simplicity, the Czech market-based DSO coordination architecture has been included in the description of the long-term market architecture. According to this classification, Table 4-9 describes the local long-term submarkets, presents the local short-term submarkets, and Table 4-11 highlights the links existing between the local long-term and the short-term markets.

In Table 4-9, the long-term local submarkets in the OneNet demonstrators are described. Since there are similarities between the two long-term submarkets of the Spanish demonstrator, a unique column is considered for this, but the differences in the attribute values are highlighted. The Czech Republic, Slovenia, and Hungary provide only one long-term submarket.

The local market architecture for long-term procurement is similar among the four demonstrators. In all the analysed designs, an auction market is run in which the FSPs submit availability bids. Only in the case of the Spanish LT-P availability and activation submarket (LT-P-A-E) the bids also include the activation term. In the case of the Slovenian demonstrator, the activation price is established based on the wholesale energy price existing at the service delivery. All the analysed designs deal with active power, the Czech and Hungarian demonstrators also focuses also on reactive power. The remuneration scheme for the FSPs is mainly of a pay-as-bid type, and the negotiating mechanism relies on discrete auctions. The Spanish demonstrator adopts the pay-as-cleared remuneration scheme as the other energy markets negotiated in auctions in Spain. Since the analysed submarkets are local, the system services of interest for flexibility procurement are congestion management and voltage control. Regarding the timing of the submarket clearing, most of the long-term submarkets close the negotiation terms one week ahead, at the latest. Only the Slovenian long-term market (LT-P-A-E) has a month-ahead timing of submarket clearing. In the Spanish demonstrator, the procurement frequency is event-based since the negotiation is opened each time that the DSO experience a need for system service. The Czech demonstrator designs a market architecture characterised by an event-based procurement frequency. The other demonstrators adopt weekly or seasonal procurement frequency. The spatial granularity of the local submarkets is the distribution system which ranges from some feeders to a set of substations. The FSPs are located in both the medium and the low voltage levels for Spain and the Czech Republic; Slovenia has LV only FSPs while Hungary MV only. In the analysed local markets, the DSO is the only buyer and plays the role of the market operator in all the demonstrators except Spain, where an independent market operator is involved as the market operator is a demo partner and aims to provide the local market platform. In the analysed local long-term markets, the DSO has exclusive access to DERs. All the demonstrators evaluate the use of compressive grid data, partial grid data, and other simple rules to consider the influence of the network on the procurement process, as highlighted in Table 4-9 by the feature timing of the grid constraint inclusion.

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Table 4-9. Comparison of OneNet demonstrators' long-term submarkets for the DSO/FSP market-based coordination

Feature	**Attribute**	**Spain**	**Czech Republic**	**Slovenia**	**Hungary**
Number of submarkets		2 a. LT-D-P-A b. LT-D-P-A-E	1 a. ALL-D-PQ-A	1 a. LT-D-P-A-E	1 a. WA-D-PQ-A-E
Submarket dimension	**Gate Opening Time (GOT)**	From more than one year-ahead to weeks ahead	Term-period agnostic	1.5 month-ahead	Week-ahead
	Timing of the submarket clearing (GCT)	Week ahead	Term-period agnostic	Month ahead	Week-ahead
	Sub-market type	Auction market	Auction market	Auction market	Auction market
Products and services	**Service**	Congestion management	Congestion Management, Voltage control	Congestion management	Congestion Management, Voltage Control
	Product procured	a. Active power Availability b. Active power Availability and activation	Active Power Availability Reactive Power Availability	Active power Availability Active power Activation	Active power Availability Active power Activation Reactive Power Availability
Location	**Level of spatial granularity**	Distribution system areas	Distribution system areas	Distribution system areas	Distribution system areas
	Responsible System Operator	DSO	DSO	DSO	DSO
	Voltage Level where resources are located	MV, LV	MV, LV	LV	MV
Roles and actors	**Who is the buyer(s)**	DSO	DSO	DSO	DSO
	Who is the seller(s)	FSP	FSP	FSP	FSP
	Who is the MO	IMO	IMO	DSO	DSO
	Participation in submarket	Optional	Optional	Optional	Optional

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Remuneration scheme		Uniform pay-as-clear	Pay-as-bid	Pay-as-bid	Pay-as-bid
Procurement frequency		Event-based on DSO call	Event based	Seasonal	Weekly
Remunerated product attribute		a. Active power Availability b. Active power availability and activation	Active and Reactive Power Availability	Active Power Availability and Activation	Active Power Availability Reactive Power Availability
Market clearing type	**Discrete; Continuous**	Discrete	Discrete	Discrete	Discrete
Methodology to represent the grid	**A. Comprehensive grid data**	X	X	X	X
	B. Partial grid data	X	X	X	X
	C. Empirical rules	X	X	X	X
Timing of grid constraints inclusion	**Definition of procurement areas**	A	A, C	A	A, B, C
	Technical pre-qualification	C	C	C	B, C
	Procurement phase	A, B	B	B	A, B
	Monitoring and activation	C		A	A, B
	Measurement, control of activation	C		A	A, B
	Settlement	C		A	A, B
Sub-market clearing objective		Minimisation of cost	Minimisation of cost	Minimisation of cost	Minimisation of cost
Access to flexibility	**System operators order for the procurement of flexibility within the submarket**	Exclusivity for DSO	Exclusivity for DSO	Exclusivity for DSO	Exclusivity for DSO

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Table 4-10 compares the local short-term submarkets of the OneNet demonstrators. The short-term DSO market-based coordination submarkets have many features in common with the corresponding long-term DSO market-based coordination submarkets described in Table 4-11 (e.g., submarket type, system service, level of spatial granularity, the voltage level of FSPs, seller, buyer, market operator, remuneration scheme, submarket clearing objective, and the methodology and timing of grid representation and constraint inclusion). All the demonstrators deal with day-ahead activation procurement, in addition, the Spanish demonstrator also can establish a real-time submarket that takes place on the same day of the service delivery. The procurement frequency is daily for all demonstrators except Spain, in which it is event-based since the market is opened by the IMO once the DSO requests the procurement of the system service. All the demonstrators except the Czech Republic are concerned with the local procurement of active power activation. Participation in the short-term local DSO market-based coordination is open to all technically qualified FSPs in all the demonstrators. However, in the Spanish, the involvement of the FSPs that have been cleared in the corresponding local availability market is mandatory. A discrete market auction characterises the short-term DSO market-based coordination submarkets of all the demonstrators.

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Table 4-10. Comparison of OneNet demonstrators' short-term submarkets for the DSO/FSP market-based coordination

Feature	**Attribute**	**Spain**	**Spain**	**Hungary**
Number of submarkets		1 a. ST-D-P-E	1 a. RT-D-P-E	1 a. DA-D-PQ-E
Submarket dimension	**Gate Opening Time (GOT)**	Day-ahead or the next hour after the DSO request (limit 11 pm)	The day of delivery	Day-ahead
	Timing of the submarket clearing (GTC)	Day-ahead (hourly and quarter of hour negotiation intervals are under consideration)	Real time	Day-ahead
	Sub-market type	Auction market	Auction market	Auction Market
Products and services	**Service**	Congestion management	Congestion management	Congestion Management, Voltage Control
	Product procured	Active Power Activation Active power Availability (optional)	Active Power Activation	Active power activation Reactive power activation
Location	**Level of spatial granularity**	Distribution system areas	Distribution system areas	Distribution system areas
	Responsible System Operator	DSO	DSO	DSO
	Voltage Level where resources are located	MV, LV	MV, LV	MV
Roles and actors	**Who is the buyer(s)**	DSO	DSO	DSO
	Who is the seller(s)	FSP	FSP	FSP
	Who is the MO	IMO	IMO	To Be Defined
	Participation in submarket	Hybrid	Optional	Optional
Remuneration scheme		Uniform pay-as-clear	Uniform pay-as-clear	Pay-as-bid

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Procurement frequency		Event-based on DSO call	Event-based on DSO call	Daily
Remunerated product attribute		Active Power Availability Active Power Activation	Active Power Activation	Active and reactive power activation
Market clearing type	**Discrete; Continuous**	Discrete	Discrete	Discrete
Methodology to represent the grid	**A. Comprehensive grid data**	X	X	X
	B. Partial grid data	X	X	X
	C. Empirical rules	X	X	X
Timing of grid constraints inclusion (primary problem)	**Definition of procurement areas**	A	A	A, B, C
	Technical pre-qualification	C	C	B, C
	Procurement phase	A, B	A, B	A, B
	Monitoring and activation	C	C	A, B
	Measurement, control of activation	C	C	A, B
	Settlement	C	C	A, B
Sub-market clearing objective		Minimisation of cost	Minimisation of cost	Minimisation of cost
Allocation principle of flexibility	**System operators order for the procurement of flexibility within a submarket**	Exclusivity for DSO	Exclusivity for DSO	Exclusivity for DSO
	TSO access to DERs	Not applicable	Not applicable	Not applicable

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Table 4-11 describes the explicit links between the long-term and the short-term DSO market-based coordination submarkets of the demonstrators analysed in Table 4-9 and Table 4-10. The submarkets of interest for studying the interaction with them are reported in the “linked submarkets” row Table 4-11. Only the Spanish and Hungarian demonstrators include the interaction between long-term availability and short-term activation submarkets. This interaction between the submarkets is established in terms of the commitment of the FSPs cleared in the availability submarket to participate in the corresponding activation submarket. If this interaction exists, the FSPs accepted in the long-term availability submarket participate in the corresponding short-term activation market. As shown in Table 4-11, the market optimisation is decentralised, and the submarkets optimisation strategy is sequential. Procurement is the market phase for coordination between the submarkets.

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Table 4-11. Comparison of the OneNet demonstrators, interactions between the long-term and short-term submarkets for the DSO/FSP market-based coordination

Feature	Attribute	Options	Spain	Hungary
Linked submarkets			1. LT-D-P-A 2. ST-D-P-E	1. WA-D-PQ-A-E 2. DA-D-PQ-E
Market optimization		Centralised; Decentralized; Distributed	Decentralized	Decentralized
Submarkets optimisation strategy		Simultaneous; Sequential; Independent	Sequential	Sequential
Interaction descriptors	**Forwarding of bids**	Yes/No	Not Applicable	Not Applicable
	Commitment to bid selection	Formal; Conditional	Not Applicable	Not Applicable
Timeframe for coordination	**Market phase for coordination between submarkets**	Technical pre-qualification		
		Procurement	X	X
		Monitoring and activation		
		Measurement		
		Control of activation		
		Settlement		

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4.2.3 Technical-based TSO-DSO coordination

As described in sections 4.2, the classification of the OneNet demonstrators is based on the demonstrated coordination type. This section describes the demonstrators that focus more on the technical aspects of the TSO/DSO coordination. The activities of these demonstrators rely on already existing markets; therefore, no market design activity is conducted, however, the relevant aspects of the markets interested by the activities of each of the demonstrators are provided.

4.2.3.1 French Demonstrator

The OneNet French demonstrator explores the implementation of STAR (System of Traceability of Renewables Activations) to define and test novel procedures for exploiting the flexibility of the connected resources. STAR is a monitoring platform that allows sharing relevant information for the settlement, but not directly undertaking it.

The use case STAR aims to build a common ledger to simplify and optimise the management of renewable production curtailments by covering the entire life cycle of a flexibility offer, from the formulation of offers to the monitoring of their activation for invoicing. The final goal is to build a platform enabling such objectives and test it for each participating entity on a chosen area of the French network. The generation curtailment monitored by the STAR platform is considered by the French rules and the contract between the system operators and generators. Therefore, the active power generation curtailment is similar to the activation of flexibility for congestion management purposes.

The flexibility services tracked by STAR are Voltage Control and Congestion Management. The STAR platform stands only as a register tracking information regarding resource activations and does not activate any resource. The core of the STAR demonstrator is proving the technical feasibility of the platform. Those aspects related to the flexibility procurement are secondary. The STAR use case does not define new products or markets; the platform to be built in the STAR use case is only aimed at tracking the producers' production forecasts, offers, flexibility activations and metering information.

The analysis of the implementation of the STAR system, which tracks the active power generation curtailment of renewable generators, is linked to the mechanisms used to define the network access agreements that specify the producers' curtailment obligations and compensation. Moreover, the STAR platform also tracks the active power generation curtailment resulting from the intraday energy market. The STAR demo makes use of existing mechanisms; therefore, no new markets or flexibility procurement mechanisms are developed within this OneNet demonstrator.

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The long-term mechanisms employed to establish the dynamic connection agreements are:

- CART: dynamic connection agreement TSO
- CARD: dynamic connection agreement DSO

Moreover, the short-term intraday flexibility market for the transmission system is monitored by the STAR platform:

- MA Market (Balancing Intraday National market)

In this market, the TSO can procure additional active power generation curtailment capability. The active power generation curtailment activated via the MA market that are tracked by STAR will only be the ones related to congestion management.

Figure 4-13 depicts an overview of the French demonstrator Market Architecture. A further description of the market aspects in line with the theoretical framework proposed in section 3 is available in Table 4-12.

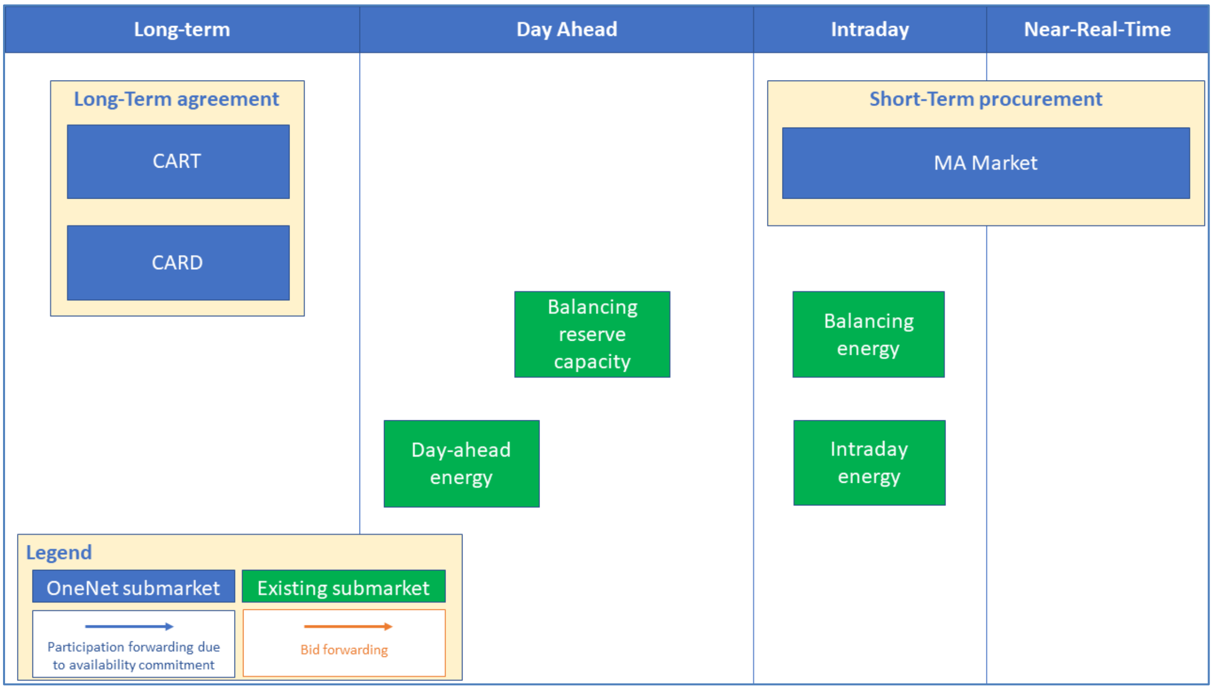

Figure 4-13. Overview of the market architecture of interest for the activities of the France demonstrator

Two flexibility mechanisms re considered in the OneNet French STAR demonstrator. These are listed next:

- Dynamic connection agreement TSO (CART);
- Dynamic connection agreement DSO (CARD).

In both flexibility mechanisms, the relevant system operators (TSO or DSO) sign agreements with the FSPs (only producers) to obtain flexibility in the form of active power generation curtailment. The STAR platform

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allows tracking the activation of the curtailment that the relevant system operator requests the DERs participating in the CART and CARD mechanisms to implement.

The Dynamic connection agreement TSO (CART) represents a mechanism in which the TSO sets up dynamic connection agreements for active power flexibility with FSPs connected to the transmission system. In these flexibility mechanisms, the activation of active power generation curtailment is procured and, in several cases, compensated. The Dynamic connection agreement DSO (CARD) represents a mechanism in which the DSO sets up dynamic connection agreements for active power flexibility with FSPs (only producers) connected at the distribution system level. In these flexibility mechanisms, the activation of active power generation curtailment is procured and, in several cases, compensated. The TSO can manage the active power generation curtailment of DERs through the DSO. First, the curtailment order is sent from the TSO to the DSO that operates the grid downstream of the relevant TSO/DSO interface. Then, the DSO dispatches the curtailment among the DERs connected to the distribution system that is bound by CARD mechanism. Participation in the CART and CARD mechanisms is mandatory for all the FSPs (producers) since this is part of the network access agreements. If required to preserve the safety of the operation of the power system, the power generation curtailment of the FSPs can be 100%.

In the short-term submarket of interest for the OneNet French STAR demonstrator, the MA submarket is included. The MA submarket is the balancing intraday, pay-as-bid, national market in which the producers register their offers the day before. In MA, the TSO picks the most relevant offer from a techno-economic point of view, which is typically the one that solves the congestion.

Regarding the STAR demonstrator, no explicit market mechanisms are used to procure flexibility from FSPs. No explicit interactions exist between the procurement mechanisms exploited and the existing markets. However, some of the following attributes can characterise the implicit relationship between CART and CARD. The TSO can only manage the flexibility available at the DSO level that is provided by aggregated FSPs. When the TSO needs flexibility to be mobilized at the TSO/DSO interface, the TSO calls the DSO to activate FSP curtailments. The DSO manages these curtailments according to its internal rules. The TSO uses the flexibility of FSPs at the DSO level, but only through the DSO.

4.2.3.2 Portuguese Demonstrator

The Portuguese demonstrator, from the OneNet western cluster, will be testing a market model coordinating the TSO's central market and the DSO's local market.

The demo has the objective to define the principles of information exchange and the market coordination schemes to enhance the operational planning activities of the TSO and DSO, namely in what concerns the use of flexibility for congestion management.

In the Portuguese cluster, two new sub-markets have been proposed:

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- TSO Congestion Management
- DSO Congestion Management

The existing submarkets that are relevant for the scope of the demonstrator are:

- Day-ahead energy
- Balancing reserve capacity
- Intraday energy

Figure 4-14. provides an overview of the market architecture of the OneNet Portuguese demonstrator. A further description of the market aspects in line with the theoretical framework proposed in section 3 is available in Table 4-13..

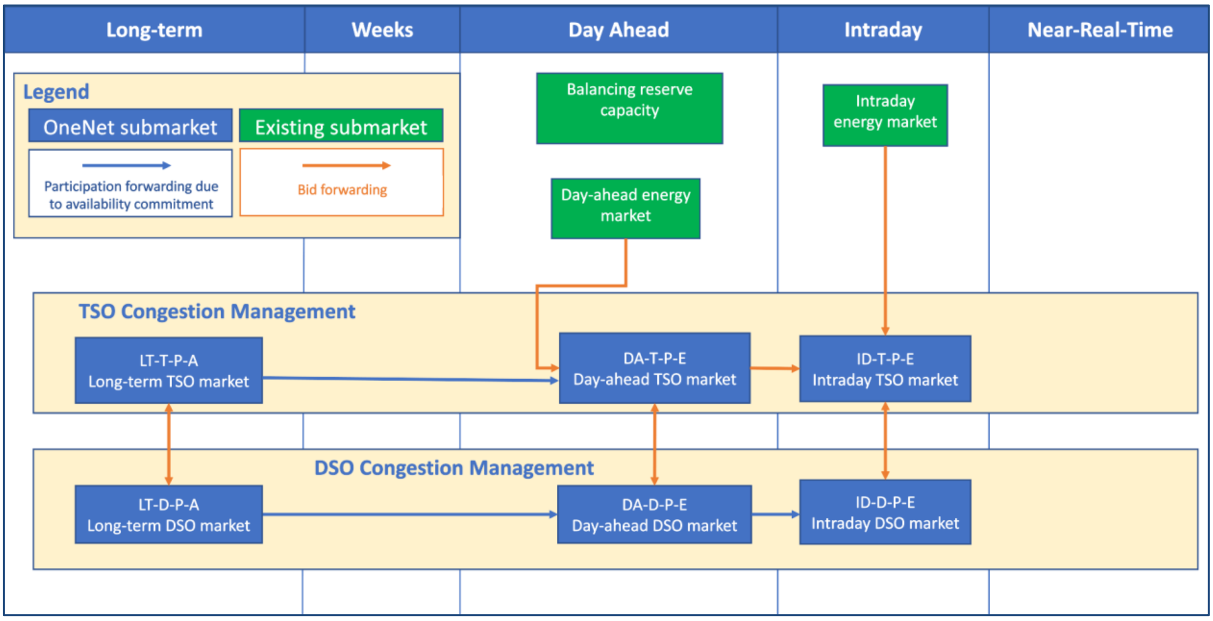

Figure 4-14. Overview of the market architecture of interest for the activities of the Portuguese demonstrator

The Portuguese market comprises 2 submarkets: DSO Congestion Management and TSO Congestion Management, for the exclusive use of the DSO and TSO, respectively. Both submarkets make use of the auction and bilateral contract procurement mechanisms.

Both submarkets consider three different timeframes for the submarkets, which are more than annually for the long-term, day-ahead, and intraday. Therefore, three submarkets are identified both for the TSO congestion management (LT-T-P-A, DA-T-P-E, ID-T-P-E) and the DSO congestion management (LT-D-P-A, DA-D-P-E, ID-D-P-E). The long-term submarkets will trade availability products that can later be activated in the day-ahead and intraday submarkets.

There exists a relationship between the balancing reserve capacity and the Day-ahead TSO submarket, which consists on ensuring that the balancing market should inform the other markets that the capacity offers

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activated/reserved by the TSO are unavailable to be used in other market, namely the new proposed markets for flexibility.

It is foreseen to have strong coordination between the DSO and the TSO submarkets to optimize the system operation and optimally address the needs of both SOs. The Portuguese demo foresees submarkets with only one buyer; the buyer can be either the TSO or DSO, interactions between the system operators are of interest for the demonstrator activities. Therefore, bilateral bid forwarding amongst these markets is considered. This interaction between the different SOs will follow a multilevel coordination strategy, considering four main properties – grid congestion location, bids' availability in each submarket, location of the resources, level of aggregation – that have multiple possible options. Each combination of these properties will lead to a different coordination scenario which will trigger a set of actions to be carried out by the SOs, to decide the forwarding and use of bids. The set of actions will be based on principles agreed by both SOs, and will consist on direct communication between the TSO and DSO to evaluate each situation, in order to obtain the solution that better fits the needs of both system operators by forwarding the necessary bids from one submarket to another.

4.2.3.3 Greek Demonstrator

The Greek demonstrator market architecture foresees one new market for the procurement of flexibility services to tackle congestion management issues, and it details the interactions with existing energy and balancing markets.

One of the main objectives of the Greek demonstrator is to improve renewable energy based on weather forecast techniques to enhance network congestion management solving.

The SO participates in the common congestion management market to acquire products to solve network congestion management needs.

In the Greek cluster, one new sub-market has been proposed:

- Common Flexibility Management submarket (ST-TD-PQ-A-E and ID-TD-PQ-A-E)

The existing submarkets that are relevant for the scope of the demonstrator are:

- Day-ahead energy
- Balancing reserve capacity
- Intraday energy
- Balancing energy

Figure 4-15 provides an overview of the market architecture of the OneNet Greek demonstrator. A further description of the market aspects in line with the theoretical framework proposed in section 3 is available in Table 4-13..

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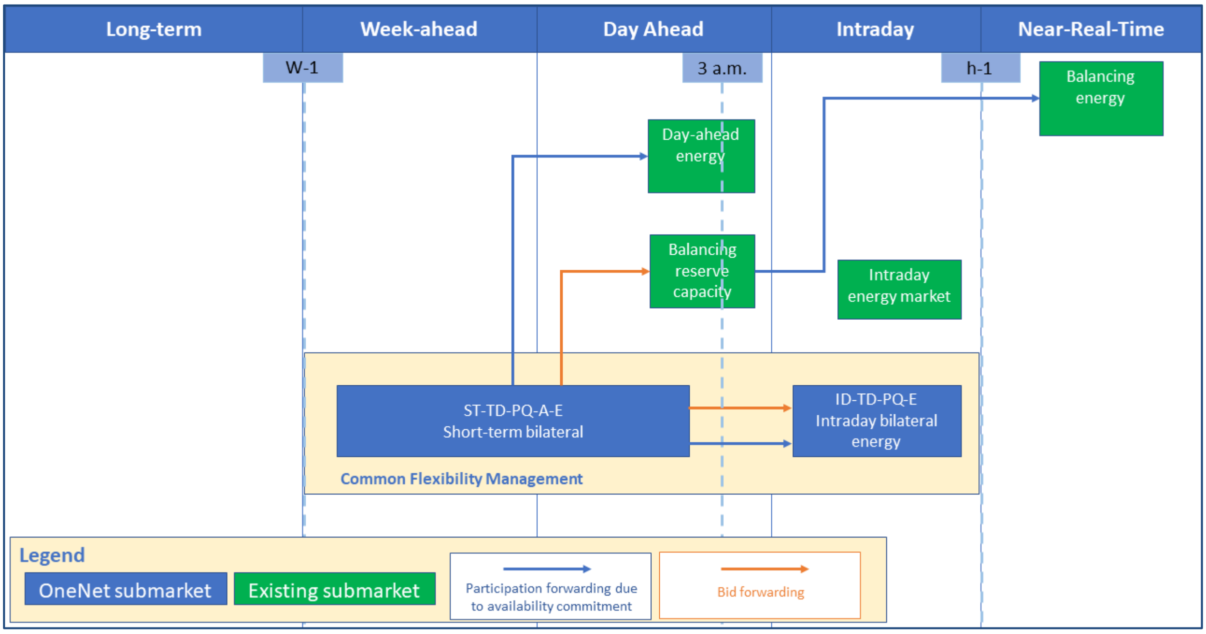

Figure 4-15. Overview of the market architecture of interest for the activities of the Greek demonstrator

The common flexibility market procures active and reactive power flexibility to provide services to the operators, both TSO and DSO, in order to alleviate problems existing at their networks, i.e., voltage control and congestion management. It comprises two different submarkets; the first submarket (ST-TD-PQ-A-E) is procurement of short-term availability and energy from FSPs through bilateral contracts from one week ahead until the day-ahead of the delivery day. The second submarket (ID-TD-PQ-E) is for energy procurement in the intraday market timeframe. The first submarket (ST-TD-PQ-A-E) mainly concerns those periodic needs that can be predicted well in advance with accuracy. The second submarket (ID-TD-PQ-E) provides to the operators the opportunity to apply corrective actions hours ahead of the actual delivery time. Due to the fact that in the Greek wholesale energy and service markets, the DER located at the distribution grid cannot participate in the balancing market and thus cannot provide services to the TSO, the Greek demonstrator follows a similar rule and the bids from resources connected to the distribution grid can provide services solely to the DSO. Therefore, TSO-DSO coordination aspect exists in the context of information exchange between the operators for security and reliability reasons. Moreover, advanced methods for congestion forecasting will be leveraged.

In the market architecture of the Greek demonstrator the bilateral agreements are negotiated by the independent market operator of the common flexibility market that negotiates bilaterally with the FSPs. The unused bids corresponding to resources connected at the transmission level are forwarding from the common flexibility to the balancing reserve capacity market.

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4.2.3.4 Comparison of the market architectures of interest for the technical-based TSO/DSO coordination

The OneNet demonstrator that focus on the TSO/DSO technical based coordination implement their activities based on the existing market architecture. The in-depth analysis of the existing market architecture is out of the scope of this deliverable; however, for the sake of completeness, the description of the market architectures of interest for the activities of the French, Portuguese, and Greek demonstrators is described in this section. For convenience of visualization, the description of the market architecture exploits two tables: Table 4-12 and Table 4-13..

Table 4-12 describes according to the theoretical market framework presented in section 3 the market architecture of the French demonstrator. The STAR platform is designed for tracking the active power generation curtailments established on the dynamic connection agreement and the MA submarkets.

Table 4-12 describes according to the theoretical market framework presented in section 3 the market architecture of the Portuguese and the Greek demonstrators. The Portuguese relies on a market architecture characterised by a DSO submarket layer and a TSO submarket layer. Conversely, the Greek demonstrator is based on a common TSO/DSO market architecture.

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Table 4-12. The architecture of the market framework of interest for the French demonstrator described according to the theoretical market framework

Feature	***Attribute***	***CART***	***CARD***	***MA***
Number of submarkets	Number of submarkets	1	1	1
Submarket dimension	Gate Opening Time (GOT)	Not applicable	Not applicable	Day-ahead
	Timing of the submarket clearing (GTC)	Not applicable	Not applicable	Day-ahead
	Sub-market type	Dynamic connection agreement (regulated mechanism)	Dynamic connection agreement (regulated mechanism)	Auction
Products and services	Service	Congestion management, Voltage control	Congestion management, Voltage control	Congestion management, Voltage control
	Product procured	Active power Availability and Activation: P generation curtailment	Active power Availability and Activation: P generation curtailment	Active power Availability and Activation: P generation curtailment
Location	Level of spatial granularity	National (Centralised procurement)	Zones at the distribution system (Decentralised procurement)	National (Centralised procurement)
	Responsible System Operator	TSO	DSO	TSO
	Voltage Level of FSPs	HV	MV	HV
Roles and actors	Who is the buyer(s)	TSO	DSO (TSO but indirectly)	TSO
	Who is the seller(s)	FSP (at transmission level)	FSP (at distribution level)	FSP (at transmission level)
	Who is the MO	Not Applicable	Not Applicable	TSO
	Participation in submarket	Compulsory	Compulsory	Optional
Remuneration scheme		Regulated: for free up to a certain quota of energy; then, compensated proportionally to the curtailed energy: Compensation = Curtailed Energy *	Regulated: for free up to a certain quota of energy; then, compensated proportionally to the curtailed energy: Compensation = Curtailed Energy *	Pay-as-bid

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		Price + Renewable energies incentive; or any other fixed value depending on the producer's contract	DA Energy Price + Renewable energies incentive; or any other fixed value depending on the producer's contract	
Procurement frequency		Event based (on connection request)	Event based (on connection request)	Daily (offers on the MA are set at a price, activated near real time, and compensated at this price)
Remunerated product attribute	Availability; Activation	Active power activation	Active power activation	
Market clearing type	Continuous; Discrete	Not applicable	Not applicable	
Methodology to represent the grid	A. Comprehensive grid data	X	X	X
	B. Partial grid data	X	X	X
	C. Empirical rules	X	X	X
Timing of grid constraints inclusion (primary problem)	Definition of procurement areas			
	Pre-qualification			
	Procurement phase			
	Monitoring and activation	A, B, C	A, B, C	A, B, C
	Measurement, control of activation	Monitored by STAR	Monitored by STAR	Monitored by STAR
	Settlement	Monitored by STAR	Monitored by STAR	Monitored by STAR
Sub-market clearing objective	Minimisation of cost	Minimisation of cost	Minimisation of cost	Minimisation of cost
Allocation principle of flexibility	System operators order (for the procurement of flexibility within a submarket)	Exclusivity for TSO	Priority for DSO (The DSO is the primary actor that "dispatches" the curtailment among the FSPs connected to its network)	Exclusivity for TSO
	TSO access to DERs	Not applicable	Yes (through the DSO and in an aggregated way)	Not applicable

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Table 4-13. The architecture of the market framework of interest for the Portuguese and Greek demonstrators described according to the theoretical market framework

Feature	***Attribute***	***Portugal TSO submarkets***	***Portugal DSO submarkets***	***Greece TSO/DSO common submarkets***
Number of submarkets	Number of submarkets	3 LT-T-P-A, DA-T-P-E, ID-T-P-E	3 LT-D-P-A, DA-D-P-E, ID-D-P-E	2 ST-TD-PQ-A-E, ID-TD-PQ-E
Submarket dimension	Gate Opening Time (GOT)	More than Annually, Day-ahead, Intraday	More than Annually, Day-ahead, Intraday	Week-ahead, Day-ahead, Intraday
	Timing of the submarket clearing (GTC)	More than Annually, Day-ahead, Hour-ahead	More than Annually, Day-ahead, Hour-ahead	Week-ahead, Day-ahead, Intraday
	Sub-market type	Auction market Or Bilateral contract	Auction market Or Bilateral negotiation	Bilateral Contract Market
Products and services	Service	Congestion management	Congestion management	Congestion Management Voltage control
	Product procured	Active power Availability and Activation	Active power Availability and Activation	Active and reactive power activation and availability
Location	Level of spatial granularity	Zones at the transmission level, Zones at distribution level - Several substations, Zones at distribution level - A substation	Zones at distribution level - Several substations, Zones at distribution level - A substation, Feeder	Zones at the transmission level, Zones at distribution level - Several substations
	Responsible System Operator	TSO	DSO	TSO and DSO
	Voltage Level where resources are located	HV	MV, LV	HV, MV, LV
Roles and actors	Who is the buyer(s)	TSO	DSO	TSO and DSO
	Who is the seller(s)	FSP	FSP	FSP
	Who is the MO	TSO	DSO	TSO
	Participation in submarket	Optional	Optional	Optional

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Remuneration scheme		Cost based (regulated)	Uniform pay-as-cleared, Bilateral Negotiation	Bilateral Negotiation
Procurement frequency		Daily, Intraday, Event-based	Daily, Intraday, Event-based	Weekly, Intraday
Remunerated product attribute	Availability; Activation	Active power Availability and Activation	Active power Availability and Activation	Active power and reactive power availability and activation
Market clearing type	Discrete; Continuous	Discrete	Discrete	Discrete
Methodology to represent the grid	A. Comprehensive grid data	X	X	To be defined
	B. Partial grid data	X		To be defined
	C. Empirical rules			To be defined
Timing of grid constraints inclusion (primary problem)	Definition of procurement areas	B	A	To be defined
	Technical pre-qualification	B		To be defined
	Procurement phase	A	A	To be defined
	Monitoring and activation	A	A	To be defined
	Measurement, control of activation	A	A	To be defined
	Settlement	A	A	To be defined
Sub-market clearing objective		Minimisation of cost	Minimisation of cost	Minimisation of cost
Allocation principle of flexibility	System operators order (for the procurement of flexibility within a submarket)	Exclusivity for TSO	Exclusivity for DSO	Exclusivity for TSO Exclusivity for DSO
	TSO access to DERs	Yes	No	No

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4.3 Common and different market aspects within OneNet demonstrators

In section 4.2, the mapping of the various market models proposed by the OneNet's demonstrators according to the conceptual market framework is provided to understand how the different markets compare.

This section aims to provide an overview of the different proposed designs and try to establish common features of all the demonstrators.

4.3.1 Actors Involved

Several actors should be defined to interact with the markets to ensure the effective operation of the proposed market architectures. In general, the actors in the new submarkets can be divided into sellers, buyers, market operators, and a responsible SO for the market.

The analysed demo questionnaires considered the following entities for each specific subdivision:

Table 4-14. Actors Involved within OneNet demonstrators

Category	Actor
Seller	FSP
Buyer	TSO and/or DSO
Market Operator	IMO, TSO, or DSO
Responsible SO	TSO, DSO, or TSO and DSO

With regards to the Sellers of the market, these are always an FSP, either in the form of a single entity, such as a large industrial consumer, or a producer; or in the form of an aggregator combining different offers from smaller producers, consumers, or prosumers, offering jointly a considerable amount of a product capable of addressing the SO's needs.

The proposed new markets consider the TSO and/or the DSO as the sole buyers of the traded products, which is in line with the purpose of the present deliverable to consider new markets for the electricity sector. These markets aim to provide products to address local and central needs, including Congestion Management, Voltage Control, Frequency Control, System Adequacy, or even Power Quality.

Amongst the several demonstrator clusters, it is common for the SOs to take also the role of MO, especially, but not only, in Bilateral and Auction markets (see section 3.1) where there is only one buyer (observed in 55% of the cases with one buyer - namely in Portugal, Hungary, Slovenia, and Poland). Therefore, the buyer, being either the DSO or the TSO, also takes the role of Market Operator. In some demonstrators, like the Spanish and Cypriot, the market operator role is assumed by an IMO.

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The SO responsible for the market can take two different forms: either a single SO takes the responsibility for the submarket in question, or the responsibility is shared across SOs, i.e. it is shared by the TSO and the DSO. Yet, this only happens when TSO and DSO have access to the same pool of flexible resources.

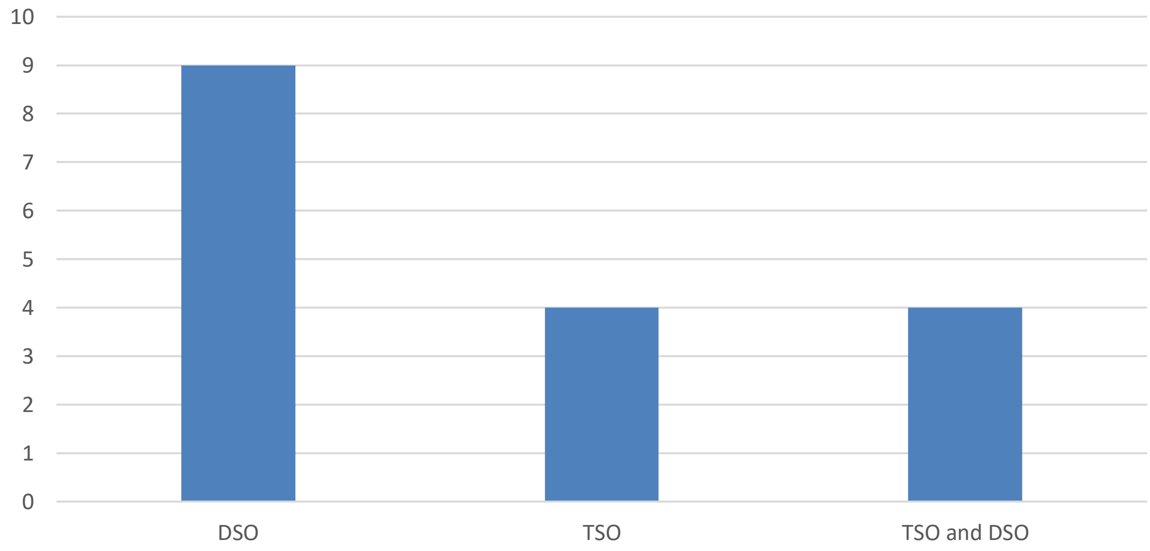

Figure 4-16. New submarkets' responsible SO

4.3.2 Procurement Mechanisms

As referred to above, a total of 17 new proposed submarkets are analysed here. According to Figure 4-17, the predominant procurement mechanism is the one based on auction markets. It should additionally be noted that some submarkets consider at this point up to two different procurement mechanisms.

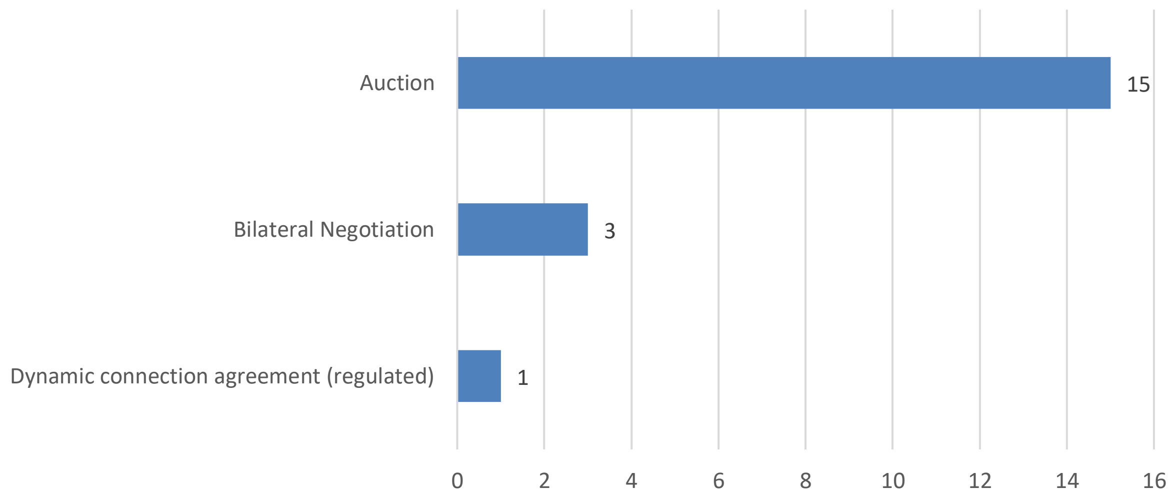

Figure 4-17. New Submarkets Procurement Mechanisms

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The procurement frequency of the several submarkets considered, which refers to how often a submarket is run, is plotted in Figure 4-18. The entire spectrum of market frequency is covered, since multiple times a day to more than annually, including event-based, with a high relevance of the Intraday and Day-ahead Markets.

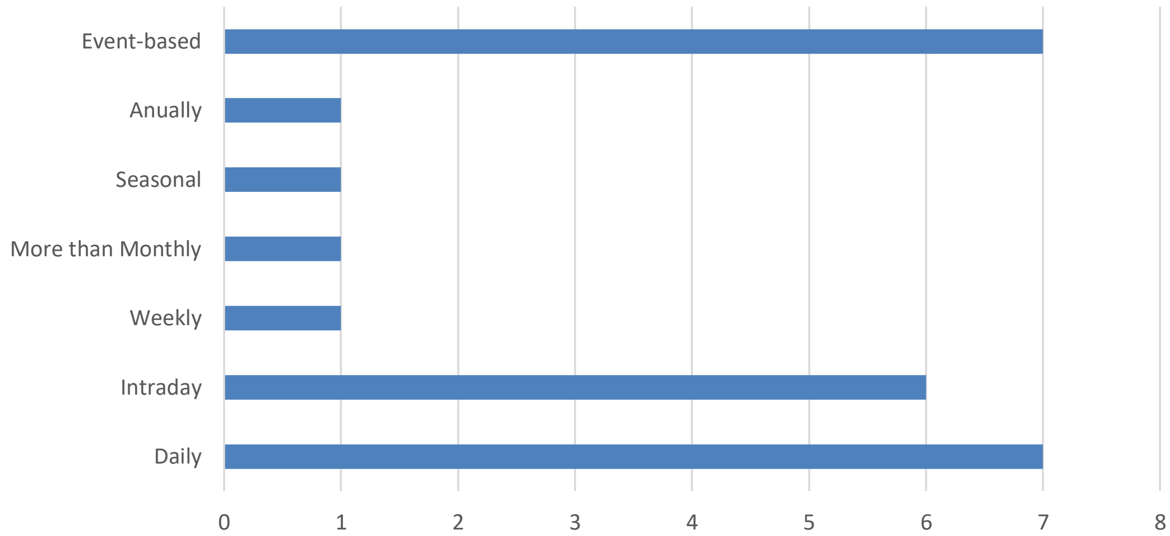

Figure 4-18. Frequency of the different submarkets

4.3.3 Proposed submarkets for the procurement of system services

The spatial granularity of each submarket is greatly correlated with the type of system service being considered and the demonstrator characteristics (Figure 4-19). As expected, markets in which the DSO is the buyer tend to have finer spatial granularity than those where the TSO is the single buyer. Furthermore, it is possible to observe that most submarkets consider a level of granularity appropriate for the distribution level, emphasising the importance of DER for the procurement mechanisms.

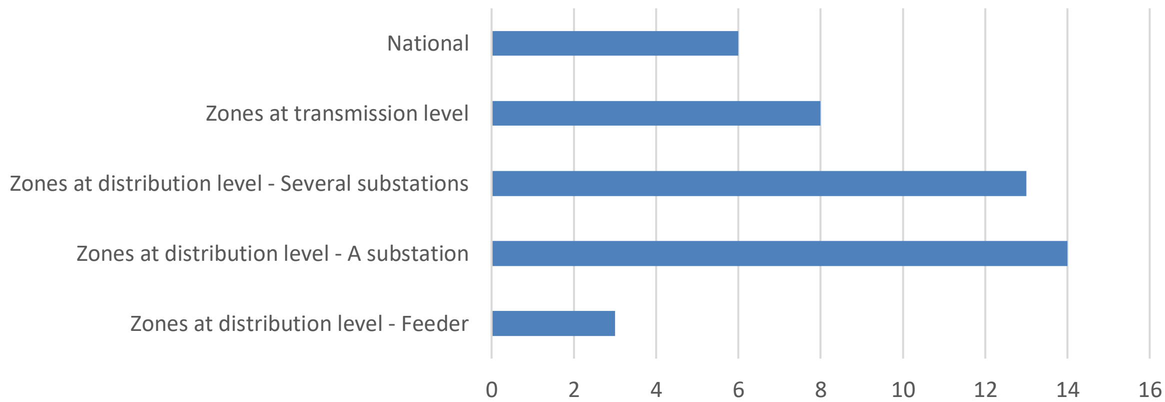

Figure 4-19. Granularity of the proposed submarkets

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The OneNet submarkets are evenly distributed according to the voltage level of the grid to which the FSPs are connected values (Figure 4-20). Some markets consider all the voltage levels, mostly in the common shared markets between TSO and DSO. Local DSO markets tend to consider the MV and LV, while the central TSO only markets tend to consider only HV (where: LV is up to 1 kV, MV from 1 kV to 35 kV included, HV from 35 kV to 245 kV included).

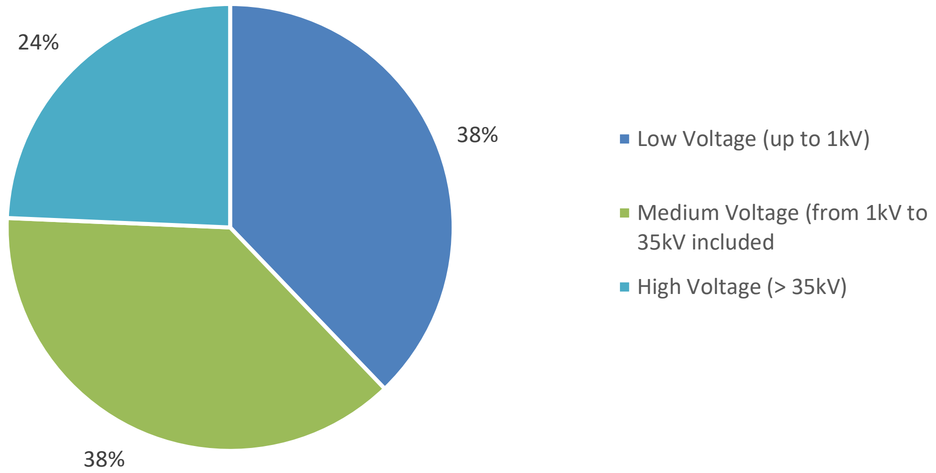

Figure 4-20. Submarkets Voltage Level

4.3.4 Services and Products procured in the markets

Network congestion management related products are, by far, the ones which are most commonly being considered to be traded in the proposed submarkets (Figure 4-21). Twenty-three analysed submarkets consider trading products capable of addressing this SO need. In addition, voltage and frequency control are also considered within a relevant number of submarkets.

Besides the aforementioned ones, some submarkets consider products for system adequacy and power quality.

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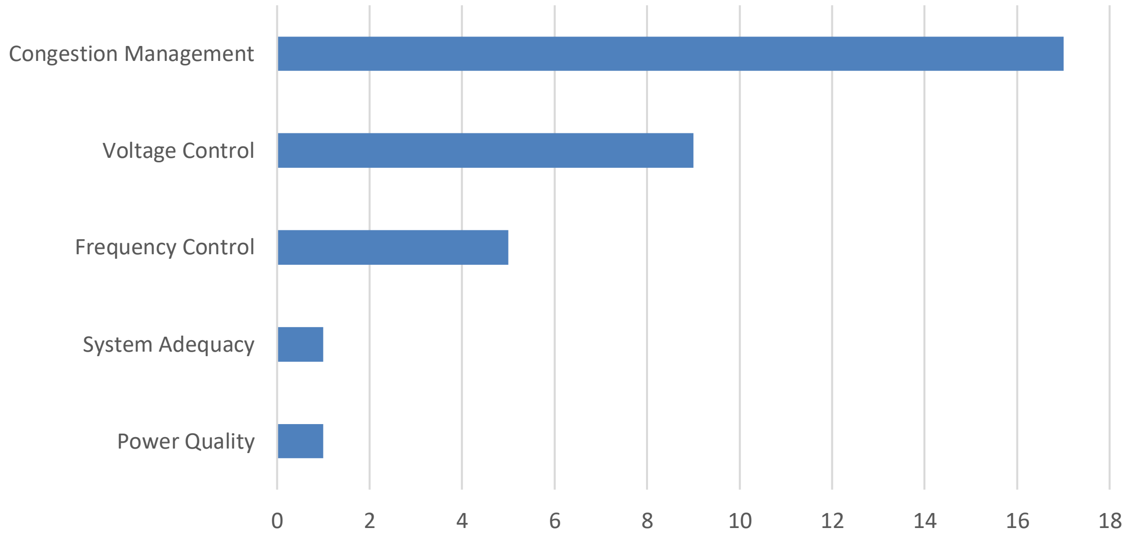

Figure 4-21. Needs addressed by the new submarkets

The type of product being procured by the SO is an essential factor to consider for this analysis (Figure 4-22). Some submarkets consider only availability products. In these cases, there should usually be, closer to the time of energy delivery, a subsequent submarket to trade committed activation products. These later submarkets usually are activation only markets. However, most of the submarkets consider the procurement of both types of products.

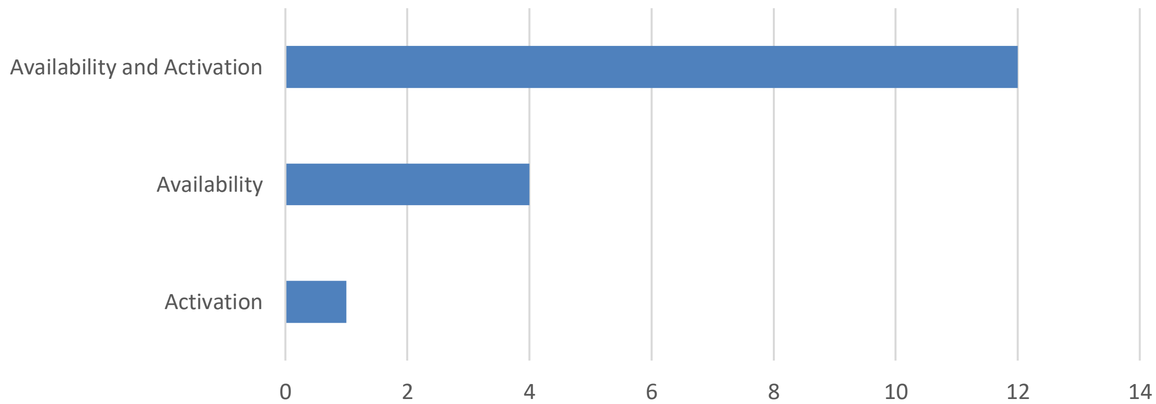

Figure 4-22. Type of submarkets' product

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4.3.5 Challenges of applying the theoretical market framework to characterise and assess markets and of integrating the flexibility submarkets with the existing ones

The activities concerning the mapping of the OneNet demonstrators according to the theoretical market framework proposed in section 3 have highlighted several challenges regarding the design of flexibility markets and their introduction in the existing electricity markets. These challenges are related to the design of the market architecture, the impacts of these markets on other grid operation activities, and their interaction with the providers.

The theoretical market framework proposes different alternatives to organize the coordination between TSO and DSO. So far, these different dimensions have been considered in the demonstrators but, at this stage of the project, relevant challenges have been identified as described in this section considering the theoretical market framework pillars.

Market architecture challenges

a. The number of submarkets: the number of formalised (sub) markets depends on the products and services definition. Therefore, the definition of such products is critical.

b. Size of the procurement area to which the FSPs belong may depend on different considerations. The definition of the boundaries of the procurement area (or bidding zone) may be based on:

    i. Grid topology and the electrical parameters of the network.

    ii. The boundaries of the area managed by the system operators involved. The boundaries of the procurement area depend on the extension of the grid under the area of responsibility

    iii. General objectives of the demonstrators: high-level objectives may lead the definition of the boundaries of the procurement area (e.g., pursuing a regional market framework as in the Northern cluster).

    iv. The cross-border implications and voltage levels need to be analysed.

c. Market roles: the roles of market participants are still to be explicitly defined. Grey areas are found for certain roles for the market operation and DSOs concerning the management of local markets.

All OneNet demonstrators faced in-depth discussion to identify the needs and define the products and the related attributes. As reported in Table 4-15, some of the OneNet demonstrators have defined products that are service agnostic (i.e. that can be used to solve several system service[30] needs), others have developed service-specific products (i.e. the product can be used to satisfy only a specific system service). Moreover, several OneNet demonstrators have defined submarkets in which various product can be traded and, therefore, could be considered as substitute products. Other OneNet demonstrators have formalised submarkets in which

[30] "system services" extends the definition provided in DIRECTIVE (EU) 2019/944 regarding ancillary services (balancing and non-frequency ancillary services) including also congestion management services [11].

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only one product is traded. Moreover, almost all OneNet market architecture shows submarket having different timing in which the same product is traded.

Table 4-15. Overview of the realization adopted by the OneNet demonstrators considering the challenge related to the definition of the number of submarkets that form the market architecture.

Service-product relationship	**Service Agnostic Product**	**Service-Specific Product**
	Cyprus; Poland; Northern cluster;	Spain; Czech Republic; Slovenia; Hungary; France; Portugal; Greece;
Product-submarket relationship	**One Product – One Submarket**	**Multiple Products – One Submarket**
	Spain; Slovenia; France; Portugal; Poland; Northern cluster	Czech Republic; Hungary; Northern cluster; Cyprus; Greece;
Product-submarket sequence relationships	**A unique Submarket for the same products**	**Multiple Submarkets in different timing for the same products**
	Czech Republic; Slovenia; Hungary; Cyprus; Poland;	Spain; Northern cluster; France; Portugal; Greece;

The OneNet demonstrator deal with the topic of the system service provision to TSOs and DSOs therefore, the challenge concerning the definition of the size of the procurement is addressed. Table 4-16 provide an overview of the contribution of the OneNet demonstrators considering the challenges related to the definition of the procurement area.

Table 4-16. Overview of the OneNet demonstrators considering the related to the definition of the procurement area

Criterion defining the locational boundaries of the market	**Countries' demonstrators**
Grid topology and the electrical parameters of the network	Spain; Portugal; Poland; Czech Republic; Hungary; Slovenia
Market operators' area boundaries	Spain; Cyprus; Czech Republic; Hungary; France; Slovenia; Greece
General objectives of the demonstrators	Northern cluster (build a regional market architecture)

The great number of partners and demonstrator involved in the OneNet project makes available for the analysis of a great variety of design for the procurement of flexibility from FSPs. As discussed, some design is characterised by a unique buyer while others include more than one system operator as a buyer of flexibility. In addition to the role of the buyer, also the role of the market operator has been of interest for the activity of the

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OneNet demonstrator. Table 4-17 provides the overview of the OneNet demonstrators classified considering which is the actor that covers the role of the market operator.

Table 4-17. Overview of the OneNet demonstrators considering the challenge of defining the market operator role

	Countries' demonstrators
The MO coincides with the buyer and/or the SO	Poland; Northern cluster; Slovenia; Hungary; France; Greece; Portugal;
IMO is the MO	Cyprus; Northern cluster; Spain; Czech Republic;

Submarket coordination challenges

a. Allocation principle of resources and products between TSOs and DSOs.

   i. Formal allocation of flexibility among buyers: Priority and exclusivity have been defined for the TSO or DSOs. In certain cases, when common markets are used, no priority nor exclusivity are pre-established but rather overall economic efficiency.

   ii. Side effects of activating flexibility: The impacts of flexibility procurement to other grid operation activities concern the effects that the activation of a flexibility provider can provoke in other areas or dimensions of the power system operation. These impacts can be classified considering if the flexibility provision simultaneously fills different needs (double procurement – positive externality) or, on the opposite side, if it creates problems to the system operation and thus creates a new need for system service (new problem creation - negative externality).

b. Allocation principle of resources and products between submarkets.

   iii. Bid forwarding: bid forwarding between submarkets that either trade activation or availability appears critical. OneNet demonstrators have identified bid forwarding across markets. The specific conditions are still to be defined. Commitment to participate in the activation submarket: participation forwarding between availability and an activation submarket requires rules to define the conditions that bind the FSPs to forward its participation and set bid parameters such as reserve prices, bid updating, and allow the participation of new FSPs to the activation submarket. It does not appear a critical element in OneNet.

   iv. Timeframe for submarkets coordination: overlapping trading time windows between markets will be present and it may require setting coordination and specific rules to avoid conflicts or undesired effects.

   v. Timeframe for coordinating the market phases: the order of the sequential market framework needs to be evaluated from the prequalification phase to the settlement.

   vi. Coordination with wholesale energy and service markets: the flexibility markets have to be coordinated with the system services markets but also with the wholesale energy market and other explicit acquisition mechanisms, such as tariffs, connection agreements.

The OneNet demonstrators contribute to the analysis of the challenges related to the submarket coordination. Table 4-18 classifies the different demonstrator according to the aspects related to the challenges of the allocation principle of resources. Different rules for the formal allocation of flexibility among buyers and submarkets are adopted among the demonstrators. One of the challenges that OneNet has to address relies on the analysis of the outcome determined by the different designs to provide recommendation and best practices.

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The results coming from the OneNet demonstrators will help the fine-tuning of the different aspects related to the submarket coordination to define the effective exploitation of the FSPs.

Table 4-18. Classification of the OneNet demonstrators considering the challenge of submarket coordination

Challenge		**Countries' demonstrators**	
Allocation principle of resources and products between TSOs and DSOs	**Formal allocation of flexibility among buyers for specific submarket**	Exclusivity for DSO	Spain; Czech Republic; Slovenia; Hungary; Greece;
		Priority for DSO	Cyprus; Portugal; Poland; France; Northern cluster;
		Exclusivity for TSO	Cyprus; Portugal; Poland; France; Greece;
		Priority for TSO	No demonstrators define it
		None	Northern cluster;
	Side effects of activating flexibility	Cyprus; Northern cluster; Poland, France (Tunnel of Warranty)	
Allocation principle of resources and products between submarkets	**Bid forwarding**	Addressed	Cyprus; Poland; Portugal; Northern cluster; Greece;
		Not addressed	Spain; Slovenia; Hungary; France; Czech Republic;
	Commitment to participate in the activation submarket	Addressed	Cyprus; Poland; Northern cluster; Spain; Hungary; Greece; Portugal;
		Not addressed	Czech Republic; Slovenia; France
	Timeframe for submarkets coordination	Overlapping submarkets	Spain; Czech Republic; Hungary; Cyprus; Portugal; Greece; Poland; Northern cluster; France
		No overlapping submarkets	Slovenia;
	Market phases	The OneNet demonstrator will test different submarkets that can put in common the different market phases. The analysis of the interactions is of interest for the further activities of OneNet.	
	Coordination with wholesale energy and service market	Addressed	Cyprus; Northern cluster; Poland; France; Portugal; Greece
		Not addressed	Spain; Czech Republic; Slovenia; Hungary;

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Market optimization challenges

a. Market optimization methodology: centralized and decentralized approaches are expected to be tested. The adopted market optimization methodology influences the allocation of flexibility among submarkets, and then, among the system operators.

b. Submarket optimisation strategy: simultaneous fulfilment of different needs, the overall procurement architecture, and the flexibility submarkets should be designed to avoid double procurements, double payments to FSPs, and discourage gaming. Therefore, this aspect influences the effectiveness of the overall market architecture.

c. Inclusion of the grid representation in the market optimisation: the activation of a flexibility service can cause a new operational problem, i.e., the activation of FSPs to solve local congestions determines active power imbalances that impact frequency control. This aspect influences the allocation principle of resources and products between TSOs and DSOs

d. Overall procurement economic efficiency: the activation of flexible resources does not have to determine the need for countermeasures to increase overall costs related to power system operation.

The challenges related to the market optimisation pillar are addressed by the OneNet demonstrators since the various design adopted for procuring system services from FSPs. Table 4-19 provides an overview of the contribution of the OneNet demonstrators to the market optimisation challenges. As can be observed, some option of market model is not addressed in OneNet and would require further investigation. Decentralised market model is of primary relevance in OneNet. The allocation of the flexibility among the different submarket optimised in a decentralised way represent a challenge that the OneNet demonstrator has to address. The outcome of the OneNet demonstrator activity has to provide inputs for defining strategies able to avoid double procurements, double payments to FSPs, and discourage gaming. Moreover, the plenty of market optimisation strategies adopted by the different OneNet demonstrators allow to experiment different ways of including the grid representation in the market phases; therefore, OneNet contributes to address the corresponding challenge. Conversely, the OneNet demonstrators, at least at this stage, have not planned to assess how the overall procurement of flexibility influence the economic efficiency. Nevertheless, the OneNet activities will provide relevant input to analyse this challenge and formulate approaches to address it.

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Table 4-19. Overview of the realization adopted by the OneNet demonstrators considering the market optimization challenges

	Countries' demonstrators	
Market optimization methodology	Centralised	Northern cluster;
	Decentralised	Spain; Czech Republic; Hungary; Northern cluster; Cyprus; Portugal; Poland
	Distributed organisation (no optimisation)	No demonstrators have defined to exploit it
Submarket optimisation strategy	Sequential	Spain; Hungary; Greece; Portugal; France; Northern Demo;
	Simultaneous	Portugal;
	Independent	Cyprus; Poland; France
Inclusion of the grid representation in the market phases	All OneNet demonstrators include the grid representation in the market phases	
Overall procurement economic efficiency change	The OneNet demonstrators plan to address these challenges in the future activities of the OneNet Project.	

Market operation challenges

a. Remuneration scheme: both pay-as-bid and pay-as-cleared are proposed for similar products and services. An in-depth analysis of these alternatives will still be considered.

b. Methodologies to define the remuneration of the products: availability and activation are proposed to be remunerated. The definition of the activation prices is considered at different timeframes.

c. Market clearing type: continuous and discrete markets will be tested.

d. Timing for the procurement of flexibility: timeframes vary from year-ahead until near-real-time. It is not clear which could be the most suitable timeframe to adopt considering the boundary characteristics.

Table 4-20 provides an overview of the OneNet demonstrator considering the feature related to the Market operation pillar. Since the different design adopted within OneNet by the demonstrator, most of the options related to the features of market operation pillar are addressed. Therefore, the comparison of the outcome from the different demonstrators contributes in addressing the challenges related to the market operation and provide best practices for an optimal market design.

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Table 4-20.Overview of the OneNet demonstrator considering the feature related to the market operation pillar

	Countries' demonstrators	
Remuneration scheme	Pay-as-bid	Cyprus; Poland; Northern cluster; Czech Republic; Hungary; Slovenia; France
	Pay-as-cleared	Cyprus; Poland; Northern cluster; Spain; Portugal;
	Bilateral negotiation	Portugal; Greece
	Cost-based or other regulated	Portugal; France
Activation procurement timing	Earlier than day-ahead	Spain; Slovenia; Poland; Northern cluster; Czech Republic; Greece; Hungary; Northern cluster
	Day-ahead	Spain; Czech Republic; Hungary; Portugal; Greece; Poland; Northern cluster
	Intraday	Cyprus; Portugal; Greece; Northern cluster; France; Poland; Czech Republic;
	Near-real-time	Spain; Cyprus; Northern cluster; France; Czech Republic;
Market clearing type	Discrete	Spain; Czech Republic; Slovenia; Hungary; Cyprus; Portugal; Poland; Greece; Northern cluster; France; Spain
	Continuous	Poland; Northern cluster (locational intraday);
Timing for the procurement of flexibility	Earlier than month ahead	Spain; Slovenia; Czech Republic; Portugal; Northern cluster; France
	From month ahead to day ahead	Spain; Hungary; Czech Republic; Greece; Poland; Northern cluster
	From day-ahead to real-time	Spain; Hungary; Czech Republic; Cyprus; Portugal; Greece; Poland; Northern cluster; France
	Event-based	Spain; Czech Republic;

Grid representation in the market process challenges

a. The comprehensiveness of the grid representation: the level of grid data is expected to vary from comprehensive grid data to empirical rules and bid limitations.

b. The comprehensiveness of the grid representation and market phases: bid constraints are expected to be considered from prequalification, procurement, monitoring, activation, and settlement. To illustrate, the characteristics of the ICT infrastructure would have a role in the process in which the grid constraints are included and the adopted computational algorithms.

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A great variety of approaches for the grid representation can be observed among the OneNet demonstrators. Table 4-21 provides the overview of the grid representation in the OneNet demonstrators considering the comprehensiveness of the grid representation adopted to make decisions regarding the operation related to the flexibility procurement (high: full grid data used, complete load flow calculation; medium: partial grid data, use of sensitivity matrix; low: grid parameters and variables, use of empirical rules). The comparison of the outcome of the OneNet demonstrators' activities will provide inputs for the analysis of the challenge related to the choice of the most effective way to include the grid representation in the different market phases.

Table 4-21. Overview of the grid representation in the OneNet demonstrators

	Values	**Demonstrators considered**
Comprehensiveness of the grid representation	**Full grid data**	Spain; Czech Republic; Hungary; Cyprus; Portugal; France; Northern cluster
	Partial grid data (sensitivities)	Spain; Czech Republic; Hungary; Portugal; Poland; France; Northern cluster
	Empirical rules	Spain; Czech Republic; Hungary; Poland; France; Northern cluster
Grid representation and market phases	**Definition of procurement areas**	All OneNet demonstrators will test the inclusion of the grid representation in some of the market phases. The particular procedure, market phase, and comprehensiveness of the grid representation depend on the goal and characteristics of each demonstrator. Sections 4.2.2.5, 4.2.1.4, and 4.2.2 contains a detailed description regarding this aspect.
	Technical pre-qualification	
	Procurement phase	
	Monitoring and activation	
	Measurement, control of activation	
	Settlement	

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5 Conclusions

The OneNet project aims to design efficient, integrated and scalable markets for DSOs and TSOs to procure system services with seamless coordination between all the players and within and across countries. This document reflects the results of the activities of Task 3.1, which provides general recommendations and guidelines on flexibility market design and the mapping of the ambitious OneNet demonstrators according to the general analysis framework defined in the Task. Based on the lessons learnt from previous projects dealing with flexibility procurement, the present document proposes a general theoretical market framework to describe the variety of flexibility procurement mechanisms that can be applied and then support the design of flexibility markets. The proposed theoretical market framework has been designed to provide a systematic tool for analysing the OneNet demonstrator initiatives to foster the harmonisation of the concepts and the vocabulary used to refer to the flexibility-market related concepts. The contribution of the mapping of the OneNet demonstrator initiatives according to this theoretical market framework is twofold. On the one hand, it provides the proof-of-concept of the theoretical market framework; on the other hand, it highlights the current gaps of the set of flexibility market models explored in the OneNet demonstrators. Finally, OneNet Task 3.1 activities have pointed out the challenges ahead regarding the market design and, in particular, the challenges of efficiently integrating brand-new markets for procuring system services within the existing electricity market architecture.

5.1 Lesson learnt from the project review

Designing efficient, integrated and scalable markets to procure system services requires taking advantage of the lessons learnt from previous projects on designing the provision of flexibility by third-party assets. Section 2 provides a review of several projects that address flexibility procurement focusing on coordination models, market concepts, and set-ups. This project review provides a high-level description of the market models of previous projects and highlights the relevant gaps of the set of designs considered in them. This project review describes in a structured way the large variety of formalisations and set-ups that have been designed, proposed, adopted, and tested for flexibility procurement. The project review highlights that there is not a single way to procure flexibility that is always valid. Boundary conditions should influence the set-up choices; however, market-based procurement through local flexibility markets involving the DSO, the TSO, or both, in an auction mechanism is of primary interest. The project review also underlined the need for a standardised or, at least, harmonised vocabulary to be employed to discuss flexibility procurement. The need to have a clear understanding of the variety of procurement frameworks based on the consideration of harmonised concepts and use of a harmonised vocabulary calls for the adoption of analytical tools and shared market model frameworks. The previously developed market model frameworks, like that in the CoordiNet project, do not describe comprehensively the system service procurement process.

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5.2 The theoretical market framework

The framework in OneNet aims to assist in the development and design of efficient, integrated, and scalable markets. It is employed to clearly and precisely categorise market concepts and ease the communication on these concepts both within the OneNet project and externally. This framework is suited to describe and assess both existing and novel market model options. Within the OneNet project, it is only applied to describe and assess market-based solutions to provide system services where TSOs and DSOs are the primary buyers.

The framework comprises five main pillars, each with several features. These five main pillars are (i) entire market architecture, (ii) sub-market coordination, (iii) market optimization, (iv) market operation, and (v) grid constraints representation. The first two pillars concern the structure of the entire market and define the nature of the coordination taking place among submarkets and stakeholders within it. The last three pillars concern the dimensions of market clearing. Some features in these pillars relate to the entire market and allow one to identify how the coordination/integration among stakeholders and markets can increase. Other features apply to the individual sub-markets and point out how the efficiency of the corresponding sub-market can be increased.

Authorities, or policymakers, may come up with an effective and efficient market model by going through the pillars of the framework and selecting, for each of their features, the appropriate value. Here, the framework is used to describe the market models explored by the demonstrators in the OneNet clusters. This framework will serve as a basis for the analyses in the subsequent tasks within WP3, where, amongst others, the gaps identified in the design of markets will be addressed to turn isolated markets into integrated, scalable and coordinated ones.

5.3 The contribution of OneNet and the challenges to improve the evolution of electricity markets in Europe

In the context of the OneNet Task 3.1 activities, the OneNet demonstrators have strongly supported and stimulated the flexibility market design process. The interactions with the OneNet demonstrators have taken place through virtual workshops and questionnaires taking advantage of their field experience. The analysis of the market models explored in the demonstrators provides the proof-of-concept for the proposed theoretical market framework. The analysis of the OneNet demonstrator and the mapping of the market models carried out according to the theoretical market framework have highlighted the main challenges of the flexibility market design and the integration of the existing submarkets into the general market architecture.

Demonstrators are exploring a large variety of market models. The interaction with the TSO is generally limited. But, among the demonstrators, different realisations of the interactions among the stakeholders of these markets have been observed. The coordination among markets and activities is required (i.e., balancing

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implications of local service activation) and is part of the future developments of the OneNet project. The relationship between the new submarkets and the wholesale energy and service market is a relevant design aspect for the demonstrators. Markets are generally used to trade availability and activation products separately. However, defining the activation time, or the expected quantities to be traded, should provide more certainty to the FSPs and reduce the risks they run, especially for new markets with no history of their behaviour. The products traded in the markets explored range from active power to active and reactive power. Focusing on the scope of the market architectures considered by the OneNet demonstrators, the Northern cluster has adopted a regional approach for defining the geographical boundaries of the submarkets. On the other hand, the rest of the demonstrators focus on national markets.

The mapping of the OneNet demonstrator according to the framework developed highlights the similarities and differences existing among the different market models explored. In any case, this mapping unifies the description made of the markets in the OneNet demonstrators and contributes to the harmonisation of the process of design of the market architectures explored. Furthermore, the activities concerning the mapping of the OneNet demonstrators highlight several challenges related to the design of the markets for procuring system services and their integration in the existing wholesale electricity market architecture. Regarding the contribution of OneNet 3.1 on the design of the novel markets, the identified challenges to be addressed to improve the evolution of electricity markets in Europe are described in are resumed in Table 5-1.

The present document provides an initial discussion of the OneNet market design. Besides, it compares and analyses from a static point of view the demonstrators based on the initial expectations about them. The next steps in the project should analyse with more detail the market design aspects that follow, among others:

1. The market sequence from the prequalification phase to the settlement;
2. The cross-border implications of the market framework adopted;
3. The multi-voltage levels dimensions;
4. The implications of the market sequence in terms of economic efficiency or gaming possibilities;
5. The interactions of the flexibility markets with the wholesale energy markets;
6. The relationship between “flexibility markets” and other implicit and explicit acquisition mechanisms, such as tariffs, connection agreements, etc.;
7. The role of the market agents.

Several challenges and gaps described in the present deliverable will be addressed in the further activities of the OneNet project, and, in particular, represent an input to Task 3.2.

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Table 5-1.Challenges to be addressed to improve the evolution of European electricity markets identified in OneNet 3.1

Challenge	Description
Market architecture challenges	The number of submarkets depends on the products and services definition. Therefore, the definition of such products is critical.
	Size of the procurement area to which the FSPs belong and the factors that influence it have to be carefully considered.
	The roles of market participants are still to be explicitly defined. Grey areas are found for certain roles for the market operation and DSOs concerning the management of local markets.
Submarket coordination challenges	Allocation principle of resources and products between TSOs and DSOs. • Formal allocation of flexibility among buyers • Side effects of activating flexibility
	Allocation principle of resources and products between submarkets. • Bid forwarding • Commitment to participate in the activation submarket • Timeframe for submarket coordination • Timeframe for coordinating the market phases • Coordination with wholesale energy and service markets
Market optimization challenges	Market optimization methodology (Centralized, decentralized, distributed)
	Submarket optimisation strategy (Simultaneous, sequential, independent)
	Inclusion of the grid representation in the market optimisation
	Overall procurement economic efficiency
Market operation challenges	Remuneration scheme (pay-as-bid, pay-as-cleared, others)
	Methodologies to define the remuneration of the products
	Market clearing type
	Timing for the procurement of flexibility
Grid representation in the market process challenges	Comprehensiveness of the grid representation
	Comprehensiveness of the grid representation and market phases

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Annex I

Project Review questionnaire

Dear OneNet partner,

The general objective of OneNet task 3.1 is to define the theoretical framework which can be used to describe in a uniform way the market concepts of the OneNet project. To achieve this result is imperative to understand the needs of the Demo partners in terms of the options that Demos have already decided to include and the options that are under consideration or expected to be developed.

This template intends to contribute by collecting the Demo perspective. The Word version should be used as a draft but the **final response of the questionnaire should be provided in the online version.**

For any doubt you may need regarding the questionnaire, please write to

José Pablo Chaves Ávila: jose.chaves@iit.comillas.edu

Matteo Troncia: matteo.troncia@iit.comillas.edu

Please not this questionnaire collects the information about the use cases independently, therefore, for example, if your Demo concerns 4 use cases, please fill the questionnaire 4 times.

Thanks for your cooperation.

Background information						
Q. 1	Please provide your Name	*please type your Name*				
Q. 2	Please provide your Surname	*please type your Surname*				
Q. 3	Please provide your Email address	*please type your Email address*				
Q. 4	Which is your Organisation?	*please type the name of your Organisation*				
Q. 5	Which is your Demo?	*please type the name of your Demo*				
Q. 6	Which is the Use Case name?	*Please provide the Use Case name*	Q. 7	Use Case Starting date	*please answer here*	
			Q. 8	Use Case Ending date	*please answer here*	

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<table>
<tr><td rowspan="13">Q. 9</td><td rowspan="13">What are the agents that the Demo is aiming to coordinate?
[e.g. TSO-DSO, TSO-TSO, DSO-DSO, DSO-FSP, other]:</td><td colspan="3">TSO-TSO</td><td colspan="3">[Y/N]</td></tr>
<tr><td colspan="3">TSO-DSO</td><td colspan="3">[Y/N]</td></tr>
<tr><td colspan="3">TSO-FSP</td><td colspan="3">[Y/N]</td></tr>
<tr><td colspan="3">TSO-aggregator</td><td colspan="3">[Y/N]</td></tr>
<tr><td colspan="3">DSO-DSO</td><td colspan="3">[Y/N]</td></tr>
<tr><td colspan="3">DSO-FSP</td><td colspan="3">[Y/N]</td></tr>
<tr><td colspan="3">DSO-aggregator</td><td colspan="3">[Y/N]</td></tr>
<tr><td colspan="3">Peer-peer</td><td colspan="3">[Y/N]</td></tr>
<tr><td colspan="3">TSO-MO</td><td colspan="3">[Y/N]</td></tr>
<tr><td colspan="3">DSO-MO</td><td colspan="3">[Y/N]</td></tr>
<tr><td colspan="3">FSP-MO</td><td colspan="3">[Y/N]</td></tr>
<tr><td colspan="3">FSP-FSP</td><td colspan="3">[Y/N]</td></tr>
<tr><td colspan="3">other</td><td colspan="3">Please specify</td></tr>
<tr><td></td><td>Which voltage levels would be covered</td><td>High Voltage</td><td>[Y/N]</td><td>Medium Voltage</td><td>[Y/N]</td><td>Low Voltage</td><td>[Y/N]</td></tr>
</table>

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	Service and product definition (Please indicate only one service per sheet)		
Q. 10	Which service will be examined or are you considering to examine?		
	• Frequency control (balancing)	*[Y/N]*	
	• Voltage control	*[Y/N]*	
	• Rotor angle stability	*[Y/N]*	
	• Network congestion management	*[Y/N]*	
	• System restoration	*[Y/N]*	
	• System adequacy	*[Y/N]*	
	• Islanded operations	*[Y/N]*	
	• Others	*[Y/N]*	
	• If others, which ones?	*please answer here*	
Q. 11	Please specify the related products (e.g. for balancing: FCR, FRR, RR, etc.)	*please answer here*	

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Features of the coordination model (Please indicate only one service per sheet)								
Q. 12	Does the Demo would define a new market model for TSO-DSO or DSO-DSO coordination?	*[Y/N]*						
Q. 13	Which is the need that would drive the coordination?	*please answer here*						
Q. 14	Which would be the level of coordination?	Information sharing	Direct supervision	Standardised product	Standardised process	Standardisation in role interaction	*Other*	
		[Y/N]	*[Y/N*	*[Y/N*	*[Y/N*	*[Y/N]*	*Please specify*	
Q. 15	Which would be the frequency of the coordination?	Single			Recurrent			
		[Y/N]			*[Y/N]*			
Q. 16	Which would be the phase of the coordination?	Prepare	Plan/forecast	Market phase	Monitoring and activation	Measurement, control of activation and settlement	*Other*	
		[Y/N]	*[Y/N*	*[Y/N*	*[Y/N*	*[Y/N]*	*Please specify*	
Q. 17	Which would be the market fragmentation	Centralized		Decentralized		Distributed		
		[Y/N		*[Y/N*		*[Y/N]*		

Q. 18	What is the need that the new market model would cover?

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	Central	*[Y/N]*	Central needs refer to the collection of services, and entailing products, which can be provided on a central level, e.g. for a certain control area as a whole. ENTSO-E defines the control area as: "a coherent part of the interconnected system, operated by a single transmission system operator"
	Local	*[Y/N]*	A local need for flexibility is branded by a locationality factor. Certain services and products are particularly characterised by a certain geographic location (e.g. congestion management for the DSO). This entails that only flexibility providers connected to the distinct location in the electricity grid can provide the required flexibility service
	Central & Local	*[Y/N]*	

Q. 19	Who would be the primary buyer of the flexibility?		
	Only TSO	*[Y/N]*	
	Only DSO	*[Y/N]*	
	Both TSO & DSO	*[Y/N]*	
	All TSO & DSO & External Stakeholder	*[Y/N]*	
	Peers	*[Y/N]*	
	Only External Stakeholder	*[Y/N]*	
	If others, which ones?	*please answer here*	
Q. 20	There would be a priority of access? If yes, please explain	*please answer here*	

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Q. 21	How many markets would be utilized or are considered to be used to buy flexibility?	
	• 1	*[Y/N]*
	• ≥1	*[Y/N]*
Q. 22	Would the TSO have access to assets on the distribution level?	*[Y/N]*
Q. 23	In case TSO and DSO can buy flexibility, does the TSO would be able to access those offers submitted to the DSO but not used by him?	*[Y/N]*
Q. 24	Please, provide some explanation	*please answer here*

	Market mechanisms (Please indicate only one service per sheet)									
Q. 25	What is the procurement mechanism under consideration considered for the service in the Use Case mentioned in Q. 10?	Considered?	Q. 26	Which are the procurement timeframes which would use or are likely to be used?						
			More than Annually	Annually	Weekly	Day-ahead	Intraday	Near to real-time (15 min)	Other	
	Flexible connection and access agreement	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	
	Dynamic distribution tariffs	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	
	Flexibility markets TSO	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	
	Flexibility markets DSO	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	
	Bilateral contracts	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	
	Cost-based	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	
	Other, please specify	*please answer here*								
Q. 27		Service - Service		Energy - Energy				Service - Energy		

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	Is it under consideration an integration of the new market, if any, with the existing ones?	*[Y/N]*		*[Y/N]*				*[Y/N]*	
Q. 28	If yes, please indicate with which ones? (e.g. day ahead, intraday, reserve)						*please answer here*		
Q. 29	Prices and schedules computed in the flexibility market would be able to modify those computed in previous markets?							*[Y/N]*	
Q. 30	If yes, please explain how this correlation is expected.							*please answer here*	
Q. 31	Which of the following processes would be considered or may be expected to be considered?	Resource registration & prequalification	Grid assessment	Bid collection	Market clearing	Metering	Baselining	Settlement	Other
		[Y/N]	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	Please, specify

	Pricing (Please indicate only one service per sheet)		
Q. 32	Indicate the pricing method which would be used or are taken into consideration for possible use for pricing the considered service		
	Pay as cleared	*[Y/N]*	
	Pays as bid	*[Y/N]*	
	Dynamic tariffs	*[Y/N]*	
	Discounts	*[Y/N]*	
	Cost-based	*[Y/N]*	
	Bilateral negotiated contract	*[Y/N]*	

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	If others, which ones?	*please answer here*

Geographical scope and network characteristics (Please indicate only one service per sheet)						
Q. 33	May the Demo involve the definition of procurement areas?	*[Y/N]*				
Q. 34	What would be the geographical scope and bidding areas for the mechanism adopted?	*please answer here*				
Q. 35	It is expected a methodology to validate technically the flexibility offers?	*[Y/N]*				
Q. 36	If yes, please indicate which of the following methods are likely to be considered for the service					
	Inclusion in the OPF	*[Y/N]*				
	Common regional AC power flow model	*[Y/N]*				
	Available Transfer Capacity	*[Y/N]*				
	Security constrained OPF (incl. cross-border flows)	*[Y/N]*				
	Others, please specify	*please answer here*				
Q. 37	It may be considered a methodology for computing network sensitivities?	*[Y/N]*				
Q. 38	Which would be the timing of grid constraints inclusion?	Prepare	Plan/forecast	Market phase	Monitoring and activation	*Other*

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		[Yes/No]	*[Yes/No]*	*[Yes/No]*	*[Yes/No]*	*Please specify*

	Flexibility service providers characteristics (Please indicate only one service per sheet)		
Q. 39	Are aggregators participating in the Demo?	*[Y/N]*	
Q. 40	For the service under analysis, please indicate what kind of resource provide are expected to provide the service.		
	Demand-side resources	*[Y/N]*	
	Storage	*[Y/N]*	
	Conventional generators	*[Y/N]*	
	Renewable generators	*[Y/N]*	
	Backup generators	*[Y/N]*	
	Facilities with both generation and consumption	*[Y/N]*	
	Others (please specify)	*please answer here*	

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Annex II

Demonstrators Review questionnaire

Questionnaire for Demos

OneNet is a project funded by the European Union as part of its Horizon 2020 program. In this project, we aim to create the conditions for a new generation of system services able to fully exploit demand response, storage and distributed generation while creating fair, transparent and open conditions for the consumer. As result, while creating one network of Europe, the project aims to build a customer-centric approach to grid operation.
The general objective of OneNet task 3.1 is to define the theoretical framework which can be used to describe uniformly the market concepts of the OneNet. This questionnaire aims at gathering the necessary information to map the set-up of the market design concepts in the different clusters with the theoretical framework.

Naturally, the different demos approach different scenarios, methodologies and designs, therefore it's expected for the market design of the different demonstrators to be in a non-identical development phase. To answer this questionnaire, a defined market structure should be already defined. If this is not the case, please provide additional information, in section 1 of the questionnaire, regarding:

- If the scope of the demo foresees the definition of a market design.
- When will the market design be ready?

For any doubt you may need regarding the questionnaire, please write to
Carlos Silva: carlos.damassilva@e-redes.pt
José Cruz: josemiguel.cruz@e-redes.pt
José Pablo Chaves Ávila: jose.chaves@iit.comillas.edu
Matteo Troncia: matteo.troncia@iit.comillas.edu

The definition of the aspects mentioned in this questionnaire is available in the glossary.

	1 – Background information	
Q. 41	Please provide your name and surname	
Q. 42	Please provide your Email address	
Q. 43	Which is your organization?	

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Q. 44	Which is the cluster of your demo?	
Q. 45	Which is your demo?	
Q. 46	Demo Country	
Q. 47	What is the objective of the demo? [provide a brief explanation of the main objectives of this demo]	
Q. 8	Will the demo define new markets? Yes: the demo will design new markets No: the demo will exploit existing markets	
Q. 9	Is the market design already defined? Yes: we have already completed the market design stage No: we are still working on the market design	

	2 – Market composition				
Q. 10	How many sub-markets are present in the Demo?	1	2	3	More? How many?

Q. 11 What types of procurement mechanism do they represent?

See the glossary.

Type/Sub-markets	Sub-market 1	Sub-market 2	Sub-market 3
Cost-based (Regulated)			
Obligation (Regulated)			
Bilateral contract			
Bilateral market			
Auction market			
Exchange market			
Pool Market			

Q. 12 What is the time frame and frequency of each sub-market?

Time Frame/Sub-markets	Sub-market 1	Sub-market 2	Sub-market 3
More than Annually			

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	(it is the procurement, not the activation signal)	Annually			
		Monthly			
		Weekly			
		Day-ahead			
		Intraday			
		Near to real time (15 min)			
		Event-based			

	3 – Sub-Markets details			
	Please, fill one table for each sub-market. Additional attributes can be added if you find them relevant as a market attribute.			
	Long-term Market.			
Q. 13	Who is the seller(s)?			
Q. 14	Who is the buyer(s)?			
Q. 15	Who is the Market Operator?			
Q. 16	Responsible SO			
Q. 17	What is procured	Availability	Activation	
Q. 18	What is remunerated	Availability	Activation	Availability & Activation (unique payment)
Q. 19	Level of granularity	National		
		Zones at transmission level		

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		Zones at distribution level	Several substations			
			A substation			
			Feeder			
Q. 20	Voltage Level	HV	MV		LV	
Q. 21	Sub-Market Objective	Maximize social welfare	Minimize costs		Highest willingness to pay	
Q. 22	Sub-Market remuneration	Pay-as-bid	Pay as cleared	Bilateral negotiation	Cost based (regulated)	
Q. 23	Market process type	Discrete		Continuous		
Q. 24	Activation confirmation (more than one options are possible)	Near real-time				
		Hour-ahead				
		Day-ahead				
		Week-ahead				
		Month-ahead				
		Year-ahead				
		Other (specify)				
Q. 25	Sub-Market procurement (Include details if they have them)	Centralized procurement One algorithm considers all voltage levels, thus including transmission and distribution. An important choice is the kind of grid data sent by the SO to the OO to take the grid constraints into account.	Decentralized procurement Each system operator has – in the perspective of roles – an allocated optimization operator.		Distributed Peer-to-peer transactions	

Inclusion of grid assessment - regarding the issue to be solved
Multiple selection allowed
In this phase is the system operators that has to buy the flexibility services that checks the effectiveness of the potential FSPs in solving the grid problem.

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Q. 26	Timing /Grid data	Comprehensive grid data Describing the electrical properties of the grid to depict its dynamics, such that the optimization algorithm is able to calculate diverse grid phenomena, select the most efficient combination of flexibilities and switching of topology	Partial grid data using essentially the sensitivities of flexibilities towards critical V/I constraints and V/I margins in the grid, e.g. for one topology	Simple rule - Empirical selection - Proportional reduction - Postal code - Others
	Definition of procurement areas			
	Technical pre-qualification			
	Procurement phase			
	Monitoring and activation			
	Measurement, control of activation and settlement			
	Other			

Inclusion of grid assessment - regarding potential issues caused by the activation of the FSPs

Multiple selection allowed

In this phase is the system operators that has to buy the flexibility services that checks if the activation of the FSPs in solving the grid problem can create secondary issues for the network operation. The activation of the FSP occurs if it does not generate any constraint violation. This check can be operated the by the SO that calls for the flexibility service or by other SOs according to the adopted coordination scheme.

Q. 27	Timing /Grid data	Comprehensive grid data Describing the electrical properties of the grid to depict its dynamics, such that the optimization algorithm is able to calculate diverse grid phenomena, select the most efficient combination of flexibilities and switching of topology	Partial grid data using essentially the sensitivities of flexibilities towards critical V/I constraints and V/I margin in the grid, e.g. for one topology	Simple rule - Empirical selection - Proportional reduction - Postal code - Others
	Definition of procurement areas			
	Technical pre-qualification			
	Procurement phase			
	Monitoring and activation			
	Measurement, control of activation and settlement			

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	Other			

	3 – Sub-Markets details				
	Please, fill one table for each sub-market. Additional attributes can be added if you find them relevant as a market attribute.				
	Short-term Market				
Q. 13	Who is the seller(s)?				
Q. 14	Who is the buyer(s)?				
Q. 15	Who is the Market Operator?				
Q. 16	Responsible SO				
Q. 17	What is procured	Availability		Activation	
Q. 18	What is remunerated	Availability	Activation	Availability & Activation	
Q. 19	Level of granularity	National			
		Zones at the transmission level			
		Zones at the distribution level	Several substations		
			A substation		
			Feeder		
Q. 20	Voltage Level	HV	MV	LV	
Q. 21	Sub-Market Objective	Maximize social welfare	Minimize costs	Highest willingness to pay	
Q. 22	Sub-Market remuneration	Pay-as-bid	Pay as cleared	Bilateral negotiation	Cost based (regulated)

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Q. 23	Sub-Market process type	

Q. 24	Activation confirmation (more than one options are possible)	Near real-time	
		Hour-ahead	
		Day-ahead	
		Week-ahead	
		Month-ahead	
		Year-ahead	
		Other (specify)	

Q. 25	Sub-Market Procurement (include details if they have them)	Centralized procurement One algorithm considers all voltage levels, thus including transmission and distribution. An important choice is the kind of grid data sent by the SO to the OO to take the grid constraints into account.	Decentralized procurement Each system operator has – in the perspective of roles – an allocated optimization operator.	Distributed Peer-to-peer transactions

Inclusion of grid assessment - regarding the issue to be solved

Multiple selection allowed

In this phase is the system operators that have to buy the flexibility services that check the effectiveness of the potential FSPs in solving the grid problem.

Q. 26	Timing /Grid data	Comprehensive grid data Describing the electrical properties of the grid to depict its dynamics, such that the optimization algorithm can calculate diverse grid phenomena, select the most efficient combination of flexibilities and switching of topology	Partial grid data using essentially the sensitivities of flexibilities towards critical V/I constraints and V/I margins in the grid, e.g. for one topology	Simple rule - Empirical selection - Proportional reduction - Postal code - Others
	Definition of procurement areas			
	Technical pre-qualification			
	Procurement phase			

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	Monitoring and activation			
	Measurement, control of activation and settlement			
	Other			

Inclusion of grid assessment - regarding potential issues caused by the activation of the FSPs

Multiple selection allowed

In this phase is the system operators that has to buy the flexibility services that checks if the activation of the FSPs in solving the grid problem can create secondary issues for the network operation. The activation of the FSP occurs if it does not generate any constraint violation. This check can be operated the by the SO that calls for the flexibility service or by other SOs according to the adopted coordination scheme.

Q. 27	Timing /Grid data	Comprehensive grid data Describing the electrical properties of the grid to depict its dynamics, such that the optimization algorithm is able to calculate diverse grid phenomena, select the most efficient combination of flexibilities and switching of topology	Partial grid data using essentially the sensitivities of flexibilities towards critical V/I constraints and V/I margin in the grid, e.g. for one topology	Simple rule - Empirical selection - Proportional reduction - Postal code - Others
	Definition of procurement areas			
	Technical pre-qualification			
	Procurement phase			
	Monitoring and activation			
	Measurement, control of activation and settlement			
	Other			

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	4 – Products and Services and their relation to Market Architecture		
Q.28	Which service will be examined or are you considering examining?	Voltage control	
		Rotor angle stability	
		Network congestion management	
		System restoration	
		System adequacy	
		Islanded operations	
		Others	

Q.29 What products will be considered to provide the services listed above?

	Product name	P/Q/other	Activation/Availability/both
Product 1			
Product 2			
Product 3			
Product 4			
Product 5			

Services/Products	Product 1	Product 2	Product 3	Product 4	Product 5
Voltage control					
Rotor angle stability					
Network congestion management					
System restoration					
System adequacy					
Islanded operations					
Others					

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Q.30	In which sub-markets will these products be traded?	Product/Sub-market	Sub-market 1	Sub-market 2	Sub-market 3
		Product 1			
		Product 2			
		Product 3			
		Product 4			
		Product 5			

Submarket coordination section

The following section regards the coordination between submarkets.
In the overall market architecture, a **submarket** is any negotiation platform in which the buyers intend to buy a good or service from the sellers to solve a specific need. To illustrate, among others, are considered submarkets: Day ahead energy market, Balancing reserve capacity, Intraday energy market, local congestion management markets.

This section aims to analyse the coordination between the new markets proposed in the context of OneNet and the existing submarket. To this aim, the coordination between submarkets is analysed **considering each couple of submarkets**.

Please, fill many tables as the number of couples that describe the interaction between a new market and an existing one. The sub-market A is the sub-market that precede in time the sub-market B.

In the following diagram is described as **an example** of the sub-market interactions. Please modify it according to your case by adding the missing information, new blocks if required, and deleting the sub-markets that are not in place in your country.

	Legend
Block	Sub-market
GOT	Gate Opening Time
GCT	Gate Closing Time
Yellow Arrow	Sub-market A creates the baseline for sub-market B
Red Arrow	Bids are forwarded from sub-market A to sub-market B
Green Arrow	Sub-market A creates the baseline for sub-market B and Bids are forwarded from sub-market A to sub-market B

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With these three arrows, the idea is to provide a high-level characterization of the relationships between adjacent markets. The yellow arrow means that sub-market B requires knowing (somehow) the output of sub-market A to start the negotiation. A baseline is that if the reference position from one market is considered for the following. To illustrate, a congestion management sub-market may require the output of the day-ahead energy market. Forwarding bids means that the bid is just sent from one market to another. The bids can be (or not) modified before being forwarded, but this aspect is not of interest at this stage. The green arrow combines these two features.					
Sub-market features					
Allocation principle of flexibility	Priority for TSO	Priority for DSO	Exclusive use for TSO	Exclusive use for DSO	No priority or exclusivity for TSO or DSO
TSO access to sources at Dx level	Yes	No			

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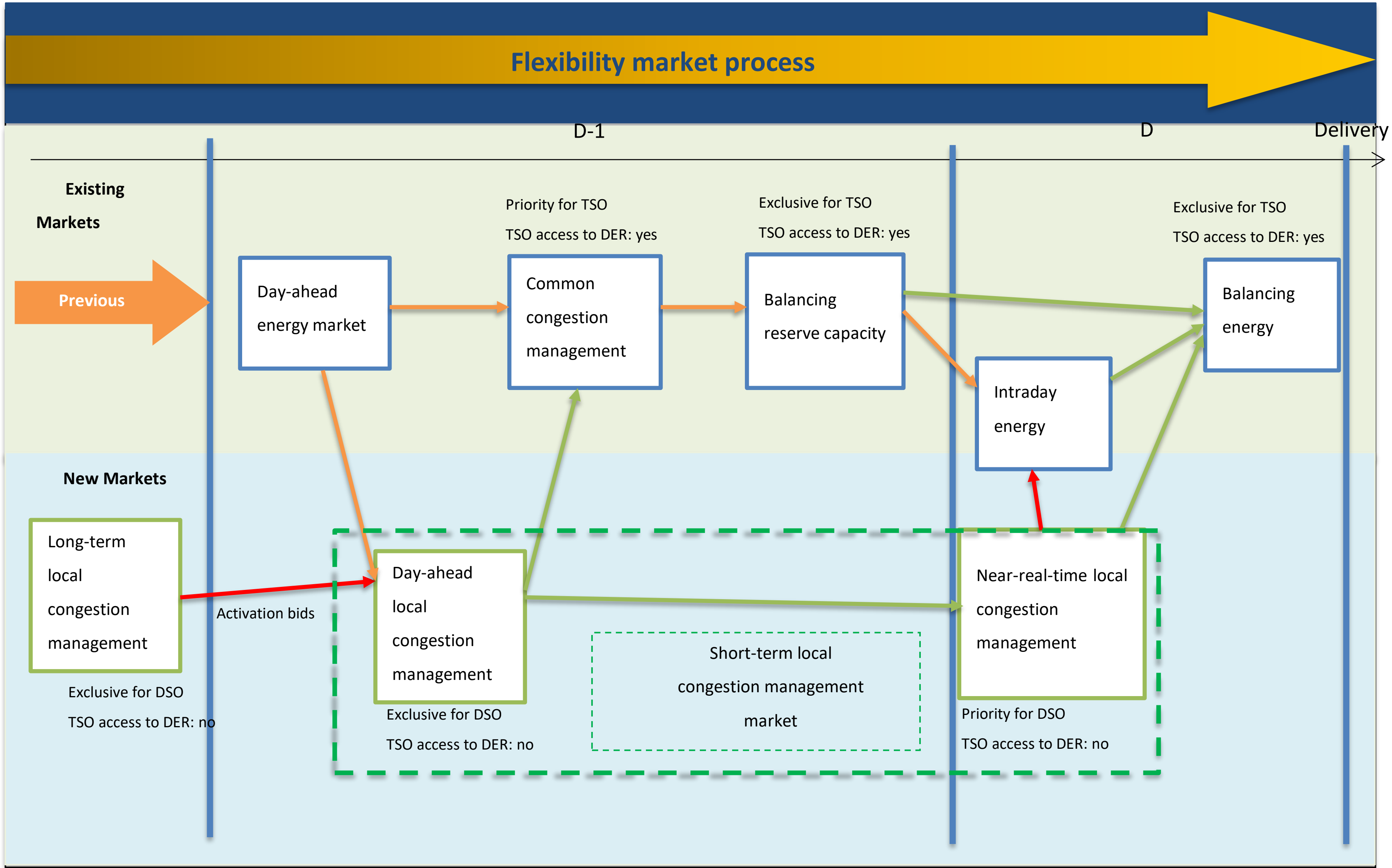

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	5 – Coordination between Sub-Markets [1/4]			
Q. 31	Submarket couple		Sub-Market A →	→Sub-Market B
		Name		
		Service		
		Product		
Q. 32	Which option for market optimization?			
	Joint optimization Both markets are optimized at the same time, ex. the joint optimization of energy and reserve markets in the US.			
	Sequential optimization One market is optimized before the other, ex. the optimization of energy and reserve markets in Europe.			

			Sub-Market A →	→Sub-Market B
Q. 33	Allocation principle	Priority for TSO		
		Priority for DSO		
		Exclusive use for TSO		
		Exclusive use for DSO		
		No priority nor exclusivity for TSO and/or DSO		

Q. 34	Market phase for coordination of sub-market	Ex-ante (A→B)	
		Simultaneous (A←→B)	
		Ex-post (A←B)	

	5 – Coordination between Sub-Markets [2/4]			
Q. 31	Submarket couple		Sub-Market A →	→Sub-Market B
		Name		
		Service		
		Product		
Q. 32	Which option for market optimization?			

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	Joint optimization Both markets are optimized at the same time, ex. the joint optimization of energy and reserve markets in the US.	
	Sequential optimization One market is optimized before the other, ex. the optimization of energy and reserve markets in Europe.	

			Sub-Market A →	→Sub-Market B
Q. 33	Allocation principle	Priority for TSO		
		Priority for DSO		
		Exclusive use for TSO		
		Exclusive use for DSO		
		No priority nor exclusivity for TSO and/or DSO		

Q. 34	Market phase for coordination of sub-market	Ex-ante (A→B)	
		Simultaneous (A←→B)	
		Ex-post (A←B)	

	5 – Coordination between Sub-Markets [3/4]			
Q. 31	Submarket couple		Sub-Market A →	→Sub-Market B
		Name		
		Service		
		Product		
Q. 32	Which option for market optimization?			
	Joint optimization Both markets are optimized at the same time, ex. the joint optimization of energy and reserve markets in the US.			
	Sequential optimization One market is optimized before the other, ex. the optimization of energy and reserve markets in Europe.			

			Sub-Market A →	→Sub-Market B
Q. 33	Allocation principle	Priority for TSO		
		Priority for DSO		
		Exclusive use for TSO		

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		Exclusive use for DSO		
		No priority nor exclusivity for TSO and/or DSO		
Q. 34	Market phase for coordination of sub-market	Ex-ante (A→B)		
		Simultaneous (A←→B)		
		Ex-post (A←B)		

	5 – Coordination between Sub-Markets [4/4]			
Q. 31	Submarket couple		Sub-Market A →	→Sub-Market B
		Name		
		Service		
		Product		
Q.32	Which option for market optimization?			
	Joint optimization Both markets are optimized at the same time, ex. the joint optimization of energy and reserve markets in the US.			
	Sequential optimization One market is optimized before the other, ex. the optimization of energy and reserve markets in Europe.			
			Sub-Market A →	→Sub-Market B
Q. 33	Allocation principle	Priority for TSO		
		Priority for DSO		
		Exclusive use for TSO		
		Exclusive use for DSO		
		No priority nor exclusivity for TSO and/or DSO		
Q. 34	Market phase for coordination of sub-market	Ex-ante (A→B)		
		Simultaneous (A←→B)		
		Ex-post (A←B)		

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