Definition of integrated and fully coordinated markets for the procurement of grid services by DSOs and TSOs

D3.2

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About OneNet

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

OneNet is funded through the EU's eighth Framework Programme Horizon 2020, "TSO – DSO Consumer: Large-scale demonstrations of innovative grid services through demand response, storage and small-scale (RES) generation" and responds to the call "Building a low-carbon, climate resilient future (LC)".

As the electrical grid moves from being a fully centralized to a highly decentralized 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. The project brings together a consortium of over seventy partners, including key IT players, leading research institutions and the two most relevant associations for grid operators.

The key elements of the project are:

1. Definition of a common market design for Europe: this means standardized products and key parameters for grid 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 organized in four clusters coming to include countries in every region of Europe and testing innovative use cases never validated before.

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List of Abbreviations and Acronyms

Acronym	Meaning
aFRR	Automatic Frequency Restoration Reserve
CACM GL	Capacity Allocation and Congestion Management Guideline
CCR	Core Capacity Calculation Region
CEP	Clean Energy Package
CM	Congestion Management
DA	Day-Ahead
DAM	Day-Ahead Market
DER	Distributed energy resources
DoA	Description of Action
DRFG	ACER Framework Guideline on Demand Response
DSO	Distribution System Operator
EBGL	Electricity Balancing Guideline
FBMC	Core Flow-Based Market Coupling
FGDR	Framework Guideline Demand Response
FSP	Flexibility Service Provider
GCT	Gate Closure Time
LV	Low Voltage
mFRR	Manual Frequency Restoration Reserves
NEMO	Nominated Electricity Market Operators
NRT-P-E	Near-real-time energy product
RES	Renewable energy sources
RR	Replacement Reserve
SDAC	Single Day-ahead Coupling
SIDC	Single Intraday Coupling
SO	System Operator
ST-P-E	Short-term energy product
TDCP	TSO-DSO Coordination Platform
TSO	Transmission System Operator
TYNDP	Ten-year Network Development Plan
VC	Voltage Control

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Executive Summary

The future power system must become increasingly flexible to accommodate the growing use of renewable energy sources. Flexibility will enable the power system to adapt to changing conditions, such as fluctuations in demand and supply, extreme weather events and grid outages. As energy demand continues to grow, integrated and scalable markets will be essential to support the transition to a low-carbon, sustainable energy future. Integrated markets allow for a greater degree of competition and efficient use of resources across a wider geographic area. Furthermore, scalable markets can accommodate the inclusion of new participants and technologies without disrupting the overall system, thereby ensuring that the market remains efficient over time.

In the light of this situation, the OneNet project aims to design efficient, integrated, and scalable markets enabling DSOs and TSOs to procure system services while offering seamless coordination between all the players within and across countries. Within the framework of markets, we define coordination as "all aspects related to processes between market actors", and integration as "all aspects related to equal market access of technologies, flexible sources and market participants". Integration and coordination of markets can bring various benefits such as maximization of welfare, increased reliability, operational security and stability, ensuring sufficient market liquidity and competition. The missing components needed to build integrated and fully coordinated markets can help policy makers and market participants to implement strategies to overcome the barriers and improve the functioning of markets. This would also help ensure that the market is developed in an inclusive, equitable and efficient manner.

Fully coordinated and integrated markets need to be also designed in a sustainable way because the future of energy depends on transitioning to a low-carbon economy. Sustainable market design ensures that adequate capacity is available in the long term by providing investment incentives ensuring security of supply. Moreover, sustainable market design guarantees that energy and flexibility are made available in an efficient way, including that markets are sufficiently liquid, cater for sufficient competition and accessible to all participants. Additionally, sustainable market design increases market penetration of RES, thus assisting in CO_2 emission reduction. Bringing all these aspects together results in a welfare increase of EU citizens.

The European Union's efforts to integrate electricity markets have so far mainly concentrated on well-established segments such as cross-border capacity allocation, day-ahead, intra-day and balancing markets. In contrast, the development of EU legislation on congestion management markets is still in its early stages, with the focus mainly on cross-zonal congestions and a general agreement that market-based congestion management should be used whenever possible. However, the emergence of more flexibility providers at the distribution level, and the increasing need for flexibility to manage renewable energy volatilities, means that a suitable legal and regulatory framework will be required to cover additional markets and products. It is worth

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mentioning that there are several ongoing developments related to the design of electricity markets at the European level. The Commission presented its first electricity market reform on 14th March 2023. In addition, the upcoming network code on demand response is expected to significantly reduce barriers to flexibility. These initiatives provide a chance for all countries within the OneNet clusters to play an active role and contribute to the development of the network code.

Objectives	Objective	Barriers	
Coordination objectives	Maximization of value stacking	B1	Insufficient coordination of flexibility markets for system services with energy markets with regard to timing.
		B2	Insufficient coordination of different system services over different timeframes, valid for all market phases, i.e., prequalification, baselining, procurement, activation, monitoring and settlement.
		B3	Lack of harmonization of flexibility products for system services for both TSO and DSO
		B4	Exclusivity clauses and non-harmonised contracts
	Cost-efficient acquisition of flexibility	B5	Coordination of explicit procurement of flexibility (flexibility markets) with implicit procurement of flexibility (tariffs, connection agreements,…)
		B6	No specific incentives in the regulatory mechanism (remuneration) that support a common approach between SOs for flexibility procurement
	Operationally efficient market procurement process for flexibility	B7	Limited cross-border coordination/integration
		B8	Limited coordination for procurement of flexibility by DSO and TSO
		B9	Lack of alignment in supporting processes such as prequalification, monitoring and settlement processes including baseline approach.
		B10	Lack of established methodology for network representation for the distribution grid
	Ability to exchange, host, and process data in a timely and secure manner	B11	ICT challenges: Large uncoordinated collection of data, timely exchange of (confidential) network information, etc.
Integration objectives	Efficient market access for all FSPs, for all voltage levels, for all technologies	B12	No appropriate baseline methodology and process established for new flexibility markets and new types of flexibility providers (e.g. low voltage flexibility)
		B13	No uniform access and registration process/platform for assets willing to participate to flexibility markets.
	Ensuring an equal level playing field for all market actors without unwanted side effects such as market power or risk of gaming	B14	Risk of gaming due to exertion of market power and/or shortcomings in the market setting
	Maximizing the benefits of sector integration	B15	Lack of coordination of markets of different carriers
		B16	Quantification of the benefits of sector integration is missing
	Adequate incentives for participation through availability of relevant information (e.g., anticipated flex needs, etc.)	B17	Unavailability of adequate information allowing FSPs to anticipate the value of their participation and hence not being able to quantify their business case

A number of objectives were defined for coordination and integration and mapped against the barriers (as shown in figure). This was done because achieving a particular objective can be complex and multifaceted, and breaking them down allowed demos to prioritize the most critical and urgent barriers. Overall, mapping barriers and solutions to integrated and coordinated markets was an important step to understand the underlying causes of barriers, identify best practices and interventions that can be replicated or adapted to other contexts.

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Through a survey conducted with the individual OneNet demonstrators we found that the barriers addressed the most were related to efficient market access, namely the lack of an appropriate baseline methodology and process and the absence of uniform access and registration processes/platforms. The barriers addressed the least were exclusivity clauses and non-harmonised contracts, lack of incentives in the regulatory mechanism and the risk of gaming. Furthermore, the solutions were segmented into three different categories: market processes, technical solutions for SOs and market access. Here we identified similarities and differences between each category. Solutions such as gate closure coordination, use of harmonised products, baselining methods and flexibility register are commonly implemented, although their characteristics, range of application and approaches differ significantly from demo to demo.

The solutions mapping also shows a balanced split between the categories of solutions implemented by the OneNet demonstrators: market processes, technical solutions for system operators and market access, with a slightly higher inclination for market access solutions. More recurrent solutions were identified within market processes and market access categories, such as the use of harmonised products and baselining methods under the market processes, or the adoption of uniform user interfaces and flexibility registers under the market access category. Finally, technical solutions appear to be the most varied among the demos, also portraying the different realities and priorities among the system operators present.

After comparing the results of mapping exercise against the most recent framework guideline on demand response (FGDR), it was also possible to identify areas where the demos are already developing solutions that are in line with the principles proposed in the guideline, as well as areas where further work may be needed to ensure compliance with the guideline. Several demo solutions, such as the use of a flexibility register, simplification of pre-qualification and measurement process align with the FGDR's technology-neutrality, ease, transparency, and accuracy principles. Additionally, the demos address data exchange related aspects, which is also one of the focuses of the FGDR. Overall, the demos are developing solutions that are in line with the principles and guidelines proposed in the FGDR.

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1 Introduction

The European Energy System is facing a substantial paradigm shift, fostered by the twin green and digital transitions required to deliver the commitments established under the Paris Agreement. In fact, the EU has been leading by example, defining ambitious climate targets, having recently revised its intentions on the reduction of greenhouse gas emissions, aspiring now for a decrease of at least 55% by 2030 compared to 1990 values and to achieve climate neutrality by 2050 [1]. These objectives are only achievable through a deep shift towards carbon neutral technologies for energy production, which should go hand in hand with an increased energy efficiency of the overall energy system, from the production to its final use, and a consequent electrification of end-use sectors. This means an increased penetration of variable and non-dispatchable renewable energy sources (RES) in the energy system, requiring a more flexible approach to its operation, whereby the connected assets are able to adapt their generation or demand patterns according to the needs of the system, thus abandoning the more traditional load following paradigm. This flexibility should be gathered not only from the generation assets connected to the network, but also on the demand side [2].

In this context, the OneNet project aims at creating the conditions for a new generation of system services[1] able to fully exploit demand response, storage and distributed generation while creating fair, transparent and open conditions for consumers. As a result, while creating one network for Europe, the project aims to build a customer-centric approach to the grid and market operation. This ambitious view is achieved by proposing new markets, products and services and creating a unique IT architecture.

1.1 Description of Task 3.2

This deliverable is part of OneNet's Work Package 3 (WP3), whose objective is to design efficient, integrated, and scalable markets for the procurement of system services by Distribution System Operators (DSOs) and Transmission System Operators (TSOs), with seamless coordination between System Operators (SOs) and between them and suppliers, aggregators, consumers and prosumers, both within and cross-countries, and in the end, to provide recommendations for the OneNet roadmap which will, based on the results of the other OneNet WPs, highlight the costs and barriers for an EU-wide implementation of market schemes and interoperability platforms with the corresponding data exchange protocols and information architecture.

WP3 is segmented into four different tasks that commonly contribute to that overall objective, by defining a theoretical market framework for innovative market design options (Task 3.1), by studying market integration aspects and interrelations of new market mechanisms with existing energy and flexibility markets (Task 3.2), by analysing potential market distortions and inefficiencies of integrated markets (Task 3.3) and by ensuring

[1] As indicated in OneNet D2.1 [3], a system service is defined as the action (generally undertaken by the system operator) which is needed to mitigate a technical scarcity or scarcities that otherwise would undermine network operation and may create stability risks.

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alignment between developed concepts of market design, the regulatory framework and the demonstrations within OneNet (Task 3.4). The interactions between the different tasks, both within and outside WP3, can be seen in Figure 1-1.

Task 3.2 "From markets in isolation to integrated and fully coordinated markets" aims to evaluate the adequacy of the market design concepts developed in the previous task (Task 3.1) and identify the missing components needed to build integrated and fully coordinated markets for the procurement of the harmonised products defined in Task 2.1. Thus, based on the results from the framework described in Task 3.1 and from inputs by the OneNet demonstrators (WP7-10), it will provide a gap analysis on the steps needed to build these fully coordinated and integrated markets. Both the barriers and solutions identified in Task 3.2 will be considered in Task 3.3 and Task 3.4. To attain its objectives, Task 3.2 started by conducting a gap analysis of the existing electricity markets (Sub-Task 3.2.1) and analysed the various components required for integrated and fully coordinated markets (Sub-Task 3.2.2).

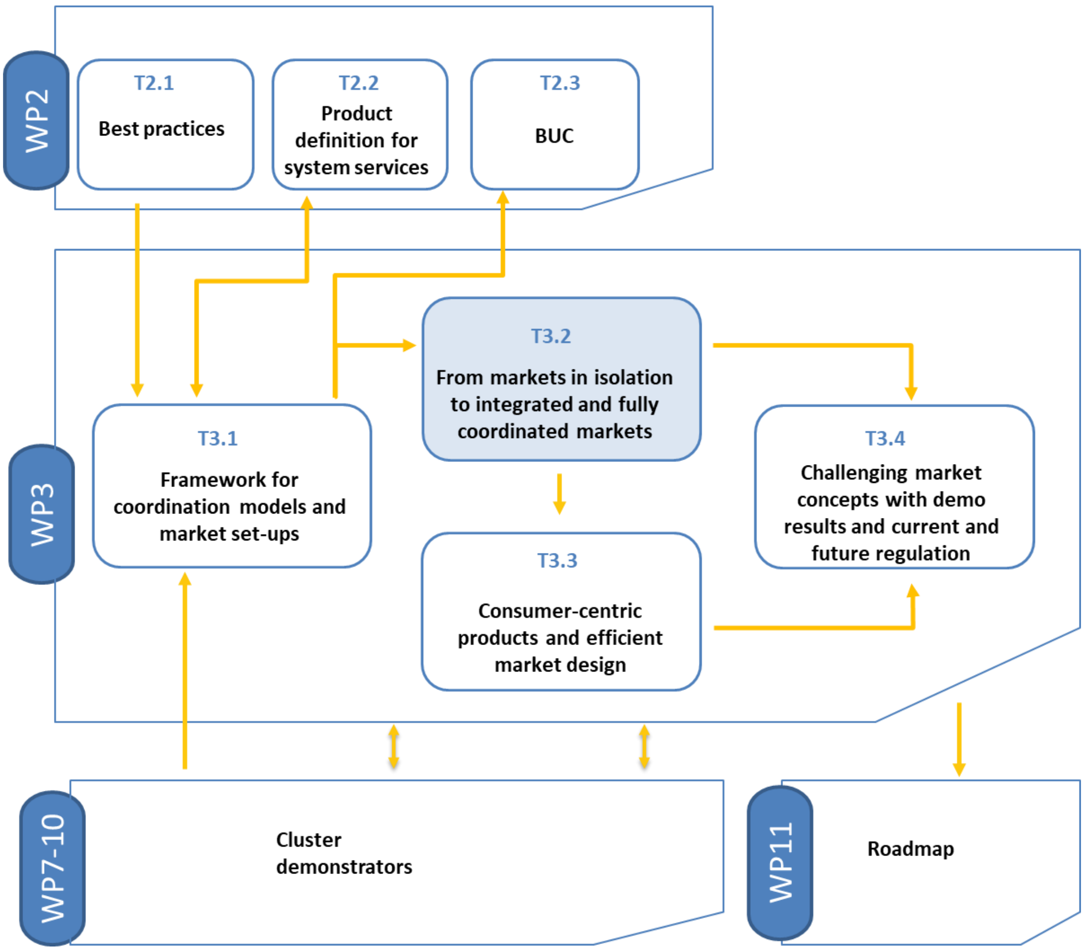

Figure 1-1: Interconnection between the OneNet Task 3.2 with other tasks and work packages in the OneNet project

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1.2 Outline of the Deliverable

The structure of this deliverable is depicted in Figure 1-2. Chapter 1 is the introductory section of the document, including the motivation, the objectives and the context of the activities carried out in Task 3.2, including how they fit into the general structure of the OneNet project. Chapter 2 presents the methodology that was used to achieve the objectives of the task. Chapter 3 describes the evolution of electricity market reforms, with special emphasis on the four waves of European legislative packages. In Chapter 4, the barriers and challenges to fully coordinated and integrated markets are identified and analysed, resulting both from the literature review and from consultation moments with the OneNet demonstrators, including the relevance of these barriers to the demos. Chapter 5 identifies the solutions and solution spaces that can foster integrated and coordinated markets, addressing if and how the different demonstrators are tackling the identified barriers. Finally, Chapter 6 presents the main findings of the Task 3.2 activities by providing closing remarks and recommendations.

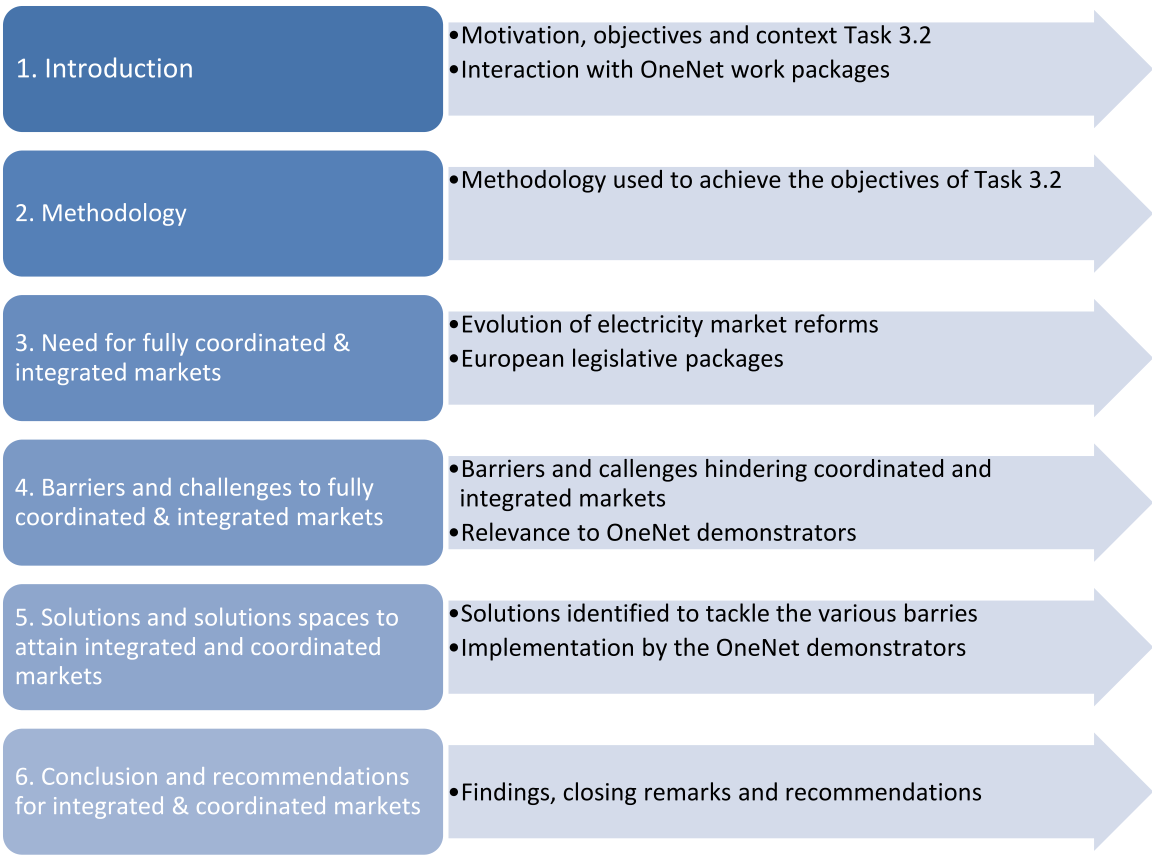

Figure 1-2: Structure of OneNet Deliverable 3.2

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2 Methodology

This chapter presents the methodology used within Task 3.2, which aims to identify the main components and recommendations for fully coordinated and integrated markets. Figure 2-1 provides an overview of this approach, which was divided into five main steps, each composed of its own research question (left side of the figure). To answer each research question, a set of methods was applied (right side of the figure).

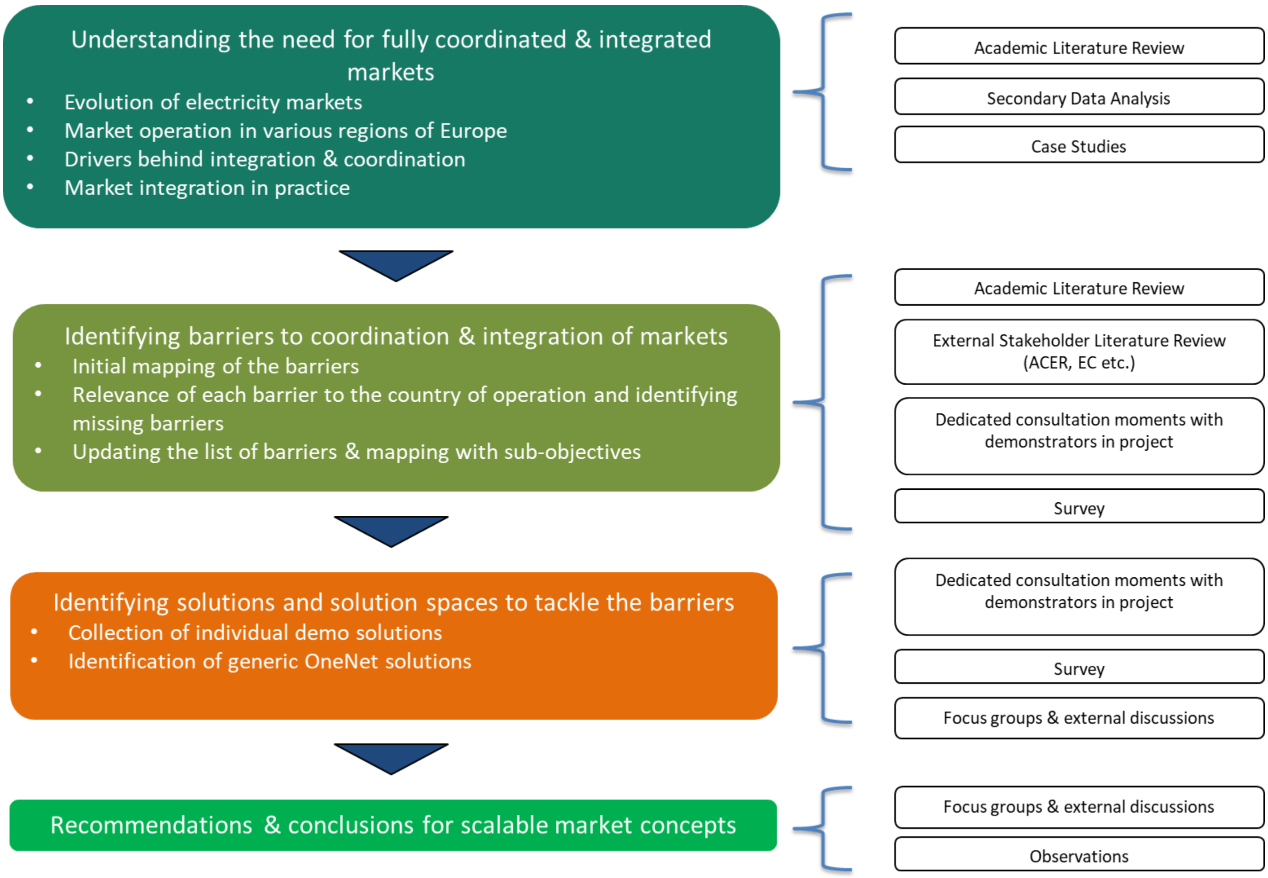

Figure 2-1: Methodology

In the first stage, the need for fully coordinated and integrated markets was assessed, mainly through an academic literature review, looking first-hand at the evolution of electricity markets and how the European political and regulatory framework has been fostering that evolution. With the EU policy trajectories defined, a state of the art of the electricity markets throughout Europe was analysed to understand how developed the various European countries are on frequency ancillary services, non-frequency ancillary services and congestion management markets, in comparison to what is expected from EU legislation, namely, from the recast Electricity Regulation and Directive. For the latter, a secondary data analysis was done based on survey results from internal and external stakeholders. Then, the main drivers towards more integrated and coordinated markets were identified, together with their high-level objectives, which can bring existing markets closer to EU policy

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expectations. The practical implementation of these drivers may not require a reinvention of solutions, which is why we also investigated existing best practices (case studies) from a variety of local flexibility projects led by TSOs, DSOs and third parties being trialled and implemented all over Europe today.

In the second stage, through an academic literature review and external stakeholder literature review, we identified barriers to attaining integrated and coordinated markets. This was an important step because barriers to integrated and coordinated markets will hinder the reaching of their objectives and high-levels objectives. Then, having the knowledge of these different barriers, a gap-analysis exercise was conducted to understand the steps needed to move from markets in isolation (e.g., for a specific System Operator, a specific country, or a specific service) to integrated and scalable markets with seamless coordination between SOs and between SOs and FSPs (e.g., suppliers, aggregators, consumers, prosumers), within and cross-countries. In the joint scope of Task 3.2 and Task 3.4, a dedicated consultation moment in the form of two workshops was organized with all the country representatives within demo clusters: Northern, Eastern, Western and Southern. The objective of the consultation moment was two-fold: 1) present the list of theoretical barriers to coordination and integration of markets to demo clusters and obtain immediate feedback on the relevance of each barrier to the country of operation and identify if Task 3.2 has missed any barrier (response captured in the form of a survey); 2) better understand each country's approach to addressing congestion management and voltage control. The information collated highlights the challenges facing the pan-European harmonisation of electricity market design. Based on the focus of most demonstrators in the OneNet project, special emphasis was put on frequency control, congestion management and voltage control.

In the third stage, we brought together the initial list of barriers and supplemented them with barriers retrieved from literature, namely, to take into account the recently published ACER Framework Guideline on Demand Response (DRFG) [4] and other additional barriers identified based on external discussions. These barriers were then mapped with the objectives from fully integrated and coordinated markets, in order to have an overview of the barriers identified for each objective.

Finally, already within the third step of the process, another consultation moment with the OneNet demonstrators was done, to identify specific and practical solutions to remove the identified barriers. These were categorised and structured into solution spaces, based on which recommendations were finally retrieved, as an output from this task.

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3 Need for fully coordinated & integrated markets

This chapter illustrates the evolution of electricity markets in Europe, focusing on the major waves of European electricity sector and market reforms which were initiated by different packages of European legislation. Secondly, it presents a high-level exercise examining frequency ancillary service markets, non-frequency ancillary service markets and congestion management markets in various regions of Europe. Thirdly, this chapter describes objectives of a sustainable electricity market design, its coordination and integration as well as the respective drivers. Finally, this chapter showcases some examples of electricity market design integration in practice.

3.1 Evolution of electricity markets

The creation of an integrated European electricity system, both from an infrastructure and market perspective, has a long tradition that traces back to the first half of the 20th century.

Already in 1921, the first cross-border interconnection for the transmission of electricity became operational between France and Italy via Switzerland, encompassing about 700 km of network infrastructure [5]. Originally, the cross-border cooperation of European TSOs was driven by the motivation to preserve system resilience and stability, make more efficient use of energy resources, and optimizing the operation of power plants. The drivers for TSOs cooperation increased with additional motivation, in the 1990s, when the vision of a fully integrated European Energy Market (Internal Energy Market – IEM) emerged as a long-term goal for the European Union and its Member States. The creation of an IEM requires both interconnecting energy networks and integrate of national energy markets across borders, two developments in which European TSOs play a key role and must closely cooperate

Figure 3-1 captures the most significant milestones of the evolution of electricity markets in Europe.

The following part presents the previous key milestones of European electricity markets and system integration toward an IEM. This evolution is characterized by several extensive electricity sectors and market reforms that were initiated through four packages of European legislation. The process of the European electricity market and system integration started in 1996 and 1998, when the European Union adopted the first legislative package (First Energy Package), consisting of two European Directives. These were aimed at opening the then monopolized European electricity and gas sectors for competition through the introduction of third-party access combined with an obligation for vertically-integrated utilities to separate generation and sales activities (competitive part) from distribution and transmission operations (regulated part) [6][2].

[2] Please note that this directive has now been replaced by [7].

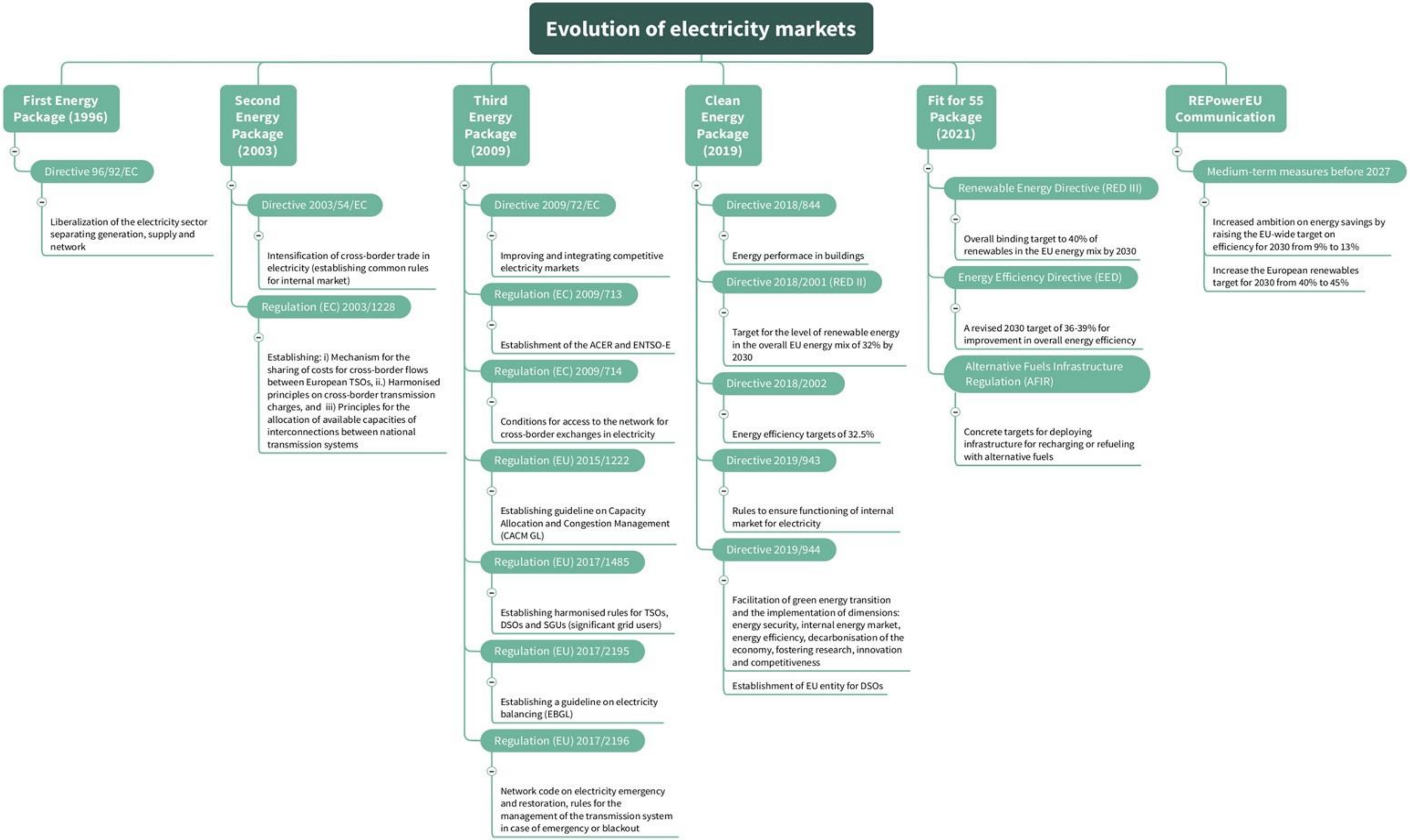

Figure 3-1: Evolution of Electricity Markets

After the First Energy Package had failed to achieve full liberalization of European electricity and gas sectors, in 2003, the European Commission went ahead with a Second Energy Package which included two further European Directives and one Regulation of dedicated measures for the intensification of cross-border trade in electricity. The adoption of this first Electricity Regulation (EC) No 1228/2003 was driven by the fact that, according to the European Commission, trade of electricity in Europe had at that time still been underdeveloped, compared with other sectors of the European common market. This first Electricity Regulation included a mechanism regarding the sharing of costs for cross-border flows between European TSOs, harmonised principles on cross-border transmission charges, and principles for the allocation of available capacities of interconnections between national transmission systems. Also, the two Directives of the Second Energy Package came with multiple changes for the European energy sector. They comprised: an obligation for legal and organizational unbundling of vertically-integrated utilities from 1st July 2004 and 1st July 2007 respectively, the introduction of a regime for regulated network access, as well as the setup of dedicated national regulatory authorities (NRAs) for the energy sector[8][3].

The European Commission's Third Energy Package of 2009, consisting of two Directives and three Regulations, led to particularly far-reaching consequences. Regulation (EC) No 714/2009, the successor to the previous Electricity Regulation (EC) No 1228/2003, pushed inter-European collaboration on energy matters to a new level by mandating to establish the Agency for the Cooperation of Energy Regulators (ACER) and the European Network of Transmission System Operators for Electricity (ENTSO-E) [10]. It also stipulated and tasked ENTSO-E with several legal mandates, including, the adoption and publication of a ten-year network development plan (TYNDP) and the elaboration of recommendations for technical cooperation between European TSOs. The Regulation also obliged ENTSO-E to elaborate detailed rules on electricity markets, system operations and network connection in the form of legally binding European network codes and guidelines. These rule books, adopted as binding European Regulations, drafted by ENTSO-E according to guidance from ACER, and are aimed to harmonize and integrate European electricity markets and systems across the long-term, short-term and balancing timeframe. The first generation of European network codes and guidelines included eight network codes[4] and four guidelines [11].

The most impactful legal act for wholesale electricity markets is the Commission Regulation (EU) 2015/1222 which establishes a guideline on capacity allocation and congestion management (CACM GL) in the day-ahead and intraday timeframe. The CACM GL makes the Single Day-ahead Coupling (SDAC) a binding target for all EU Member States. The SDAC project serves to create a single pan-European cross-zonal day-ahead market for

[3] Please note that this regulation has now been replaced by [9].

[4] These are 3 connection codes: (i) network code on requirements for grid connection of generators (EU) 2016/631, (ii) demand connection network (EU) 2016/1388, and (iii) requirements for grid connection of high voltage direct current systems and direct current-connected power park modules network code (EU) 2016/1447, 2 operational codes: (iv) electricity transmission system operation guideline (EU) 2017/1485, and (v) electricity emergency and restoration network code (EU) 2017/2196, and 3 market codes: (vi) capacity allocation and congestion management guideline (EU) 2015/1222, (vii) forward capacity allocation guidelines (EU) 2016/1719, and (viii) electricity balancing guideline (EU) 2017/2195.

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electricity through an efficient allocation of scarce cross-border transmission capacity, thereby maximising social welfare. This is achieved by the coupling of wholesale electricity markets from different regions via a common algorithm “EUPHEMIA”, simultaneously considering cross-border transmission constraints. At the time of writing, the day-ahead electricity markets of most EU Member States have already been fully coupled [12]. In total, 30 European TSOs and 17 nominated electricity market operators (NEMOs) take part in the SDAC project which is governed by the Day-Ahead (DA) Operational Agreement (DAOA). The overall welfare gains expected from extending SDAC to all EU borders amount to over 150 Mn EUR/year [13]. After completion of the SDAC project, overall economic efficiency of European electricity wholesale markets is anticipated to further increase. In the first-half of 2022 flow-based implicit allocation was implemented in the Core Capacity Calculation Region (CCR) in the framework of the Core Flow-Based Market Coupling (FB MC) Project as well as the Croatian-Hungarian border will be included in the SDAC coupling [14]. Next to SDAC, there is also the Single Intraday Coupling (SIDC) project which strives for a single European cross-zonal electricity market for the intraday timeframe. The SIDC allows for a more efficient and liquid intraday market by matching orders across multiple countries and across multiple power exchanges. This is beneficial for participants on both sides of the market, as it gives them access to a larger pool of orders to fill. The integration of additional countries into the SIDC takes place in several phases also referred to as “waves”. The SIDC was launched on 12th June 2018 across 14 countries (1st wave). In the first 16 months of its operation, over 25 million trades were completed in the countries involved. On 19th November 2019, SIDC was extended to seven further countries bringing the total number of participating countries to 22 (2nd wave) [15]. A third go-live of the SIDC in September 2021 included Italy. At the time of writing, SIDC comprises 25 countries after the successful coupling of Greece and Slovakia in November 2022.

Another critical piece of legislation for European electricity markets, enacted as a guideline under the Third Energy Package, is the Commission Regulation 2017/2195 which establishes a guideline on electricity balancing, (EB GL). Its purpose is to harmonize European balancing markets through a wide set of technical, operational and market rules. As a part of operationalising EB GL requirements, three pan-European balancing energy platforms were set up to harmonize cross-border exchange of balancing energy between EU Member States: MARI (Manually Activated Reserves Initiative) for Manual Frequency Restoration Reserves (mFRR), PICASSO (Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation) for Automatic Frequency Restoration Reserve (aFRR), and TERRE (Trans European Replacement Reserves Exchange) for Replacement Reserves (RR). These platforms alongside IGCC (International Grid Control Cooperation) platform, complete the implementation of the European target market design for balancing [16]. The EB GL stipulates common principles, harmonised products, and methodologies for European balancing markets.

In 2019, the European Commission launched its fourth and latest legislative package for the electricity and gas sector, the so-called Clean Energy for all Europeans Package (short: CEP). It comprises of updated versions

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of both the Electricity Directive and Regulation, a new Regulation on Risk Preparedness in the electricity sector, and a revised ACER Regulation. The CEP aims to facilitate the clean energy transition and addresses five dimensions of the Energy Union: Energy security, ICM, energy efficiency, decarbonisation of European economies, and the fostering of research, innovation and competitiveness [17]. The package includes eight legislative acts and measures aimed at facilitating clean energy transition. One important change in terms of European energy governance was the establishment of the EU DSO Entity according to the updated Electricity Regulation. The EU DSO Entity, an association of all EU DSOs, has been formally set up in mid-2021, and ensures close cooperation between TSOs and ENTSO-E regarding the integration of European electricity markets and systems[5].

In light of the EU's commitment to cut greenhouse gas emissions by 2030 by 55%, the European Commission presented the Fit for 55 package in 2021[6], which proposes several measures. The recast Renewable Energy Directive (REDIII) proposes to increase the overall EU binding target of renewables to a new level of 40% in the EU energy mix by 2030 compared to 32% in the Directive 2008/221 [18]. REDIII aims to foster a better energy system integration and to contribute to climate and environmental objectives including the protection of biodiversity [19]. The Energy Efficiency Directive (EED) proposes more ambitious and legally binding targets for improvement in overall energy efficiency (final and primary) by 2030 (up to 36-39% compared to the 32.5% target proposed in Directive 2018/2002) as well as for reducing total energy demand by 9% relative to a baseline scenario [20]. Finally, the Alternative Fuel Infrastructure Regulation (AFIR) calls for mandatory targets for the infrastructure for alternative fuels in line with the larger EU Green Deal goal of reducing GHG emissions in transportation by 90% by 2050. These measures are designed to ensure a quicker roll-out of low emission transport modes, as well as the infrastructure and fuels needed to support them [21].

In May 2022, the European Commission proposed the REPowerEU Plan, a policy that aims to reduce the EU's dependence on Russian fossil fuels and to speed up the European green energy transition through energy savings, diversification of energy supplies, and accelerated roll-out of renewable energy [22]. As a part of REPowerEU, several medium-term measures are proposed. The plan includes a proposal amending the REDIII to increase the 2030 target for the proportion of renewable energy in final energy consumption from 40% to 45%. Furthermore, REPowerEU plan proposes to enhance long-term energy efficiency measures, including an increase from 9% to 13% of the binding energy efficiency target under the Fit for 55 package.

Further in October 2022 EC published a communication on Digitalising the Energy System Action Plan (DESAP), setting out actions to digitalise the energy sector to improve efficiency and renewable integration [23].

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[5] The new EU DSO Entity will allow the creation of a single European representation of DSOs, reflecting the new central role of DSOs in the energy transition. It will create a forum of expertise and exchange of views among DSOs on a range of topics that relate to their business, as well as ensuring consultation on Guidelines and participation in the elaboration of Network Codes which are relevant for distribution networks. The new entity will also promote TSO-DSO cooperation for the optimal and coordinated operation and planning of DSO/TSO network, as well as the technical expertise dialogue with other stakeholders.

[6] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_3131

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A joint task force was established between the EU DSO entity and ENTSO-E to ensure cooperation and support on the development of a Digital Twin of the European Electricity Grid to promote digitalisation following the Declaration of Intent (DoI) signed on 20th December 2022 [24]. As a part of the Digital Twin, the following five areas were selected for the development of innovative solutions and coordination of investment:

- observability and controllability.
- efficient infrastructure and network planning.
- operations and simulations for a more resilient grid.
- active system management and forecasting to support flexibility and demand response.
- data exchange between TSOs and DSOs.

In order to monitor these digital investments within DESAP, common smart grid indicators will be defined to measure the development of the Digital Twin throughout the EU Member States, a work that will be led by ACER and the national regulatory authorities.

Most of EU's regulatory and legislative efforts so far regarding the integration of electricity markets are focussed on cross-border capacity allocation, day-ahead, intra-day and balancing markets, as these segments are the most mature and liquid ones. EU legislation on congestion management markets is still in nascent stage, mainly focusing on cross-zonal congestions and indicating general provisions that congestion management should be market-based whenever possible. However, as more flexibility providers emerge, especially at distribution level, and as both market parties and system operators require more flexibility to manage volatilities from renewable energy sources, a fit-for-purpose legal and regulatory framework will be needed to cover more markets and products.

Article 59(1) of the electricity regulation lays down the foundation for the development of network codes on demand response (DR) [9]. The revised Electricity Regulation already introduced rules aimed to incentivise DSOs to procure flexibility resources and to facilitate the participation of demand response, storage and distributed energy providers in wholesale and balancing markets. In 2020, European Commission introduced a priority list for the development of network codes and guidelines for period 2020-2023 focusing on new harmonized rules on aggregation, energy storage, demand curtailment, demand side response and cybersecurity [25]. In June 2021, ENTSO-E published a joint report titled "Roadmap on the Evolution of the Regulatory Framework for Distributed Flexibility" together with CEDEC, E-DSO, Eurelectric and GEODE [26]. In preparation for this publication, ENTSO-E and DSOs had identified key regulatory hurdles to be resolved, in order to facilitate the participation of distributed energy resource providers in flexibility markets. In October 2021, EC mandated ACER to perform initial scoping of Network Codes on DR. Further on 20th December 2022, the ACER submitted a framework guideline for the development of a network code DR to the European Commission. Once ACER's framework guideline is cleared by the European Commission, ENTSO-E and the EU DSO Entity will be asked by the Commission to draft (within 12 months) the proposal for the new binding EU rules. This future network code will enable DERs to participate in market-based mechanisms for services procured by TSOs and DSOs on an equal basis with other resources.

3.2 Examination of electricity markets in various European regions

The examination of electricity markets in various European regions is a relatively high-level exercise, therefore, not all the details are captured within this deliverable. The collated information highlights the challenges facing the pan-European harmonisation of electricity market design. Based on the focus of most demonstrators in the OneNet project, special emphasis was put on frequency control, congestion management and voltage control. In the following sections, we discuss each of these markets.

3.2.1 Frequency Ancillary Services Markets

Frequency Ancillary Services are the variety of operations on the electricity network required to maintain system frequency within a predefined stability range and compliance with respect to the desired quality. The development of frequency ancillary services is becoming more and more crucial for a secure operation of the European power system in the light of the increasing infeed of electricity from renewable energy sources. The very basic requirement for secure operation of a power system is to maintain the balance between generation and consumption at every moment in time. Until recently, the process of utilizing balancing energy and its procurement via balancing electricity markets has largely remained a purely national undertaking. However, with the entry into force of the EB GL in 2017, a starting point has been set for the integration of national balancing markets towards a harmonized European one [16].

The framework under the EB GL is designed to ensure a common approach to the operation of European balancing markets, including the definition of standard products for balancing energy, balancing capacity, and replacement reserves. The EB GL ensures that a coherent approach for these aspects is applied across all EU Member States, thus creating a level playing field for market participants. The framework also includes a range of measures to ensure that balancing markets operate efficiently and transparently. e.g., by standardizing balancing product requirements for the provision of balancing services, promoting open access to the balancing market, and developing common rules for the provision of balancing services. The EB GL also includes several measures to ensure that the balancing markets are competitive and that prices are determined in a transparent and non-discriminatory way, for instance by providing market participants with all necessary information for making informed decisions.

Another important instrument for the integration of European balancing energy markets under the EB GL is the establishment of four European platforms for the exchange of balancing energy from frequency restoration reserves, replacement reserves, and for the operation of the imbalance netting process to ensure efficient and timely balancing energy supply and demand. The four balancing platforms are already in operation in 2022: Go-live of PICASSO (June 2022), MARI (Oct 2022), and TERRE and IGCC already previously operating [27]. These new

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platforms will likely provide greater liquidity for balancing markets, reduce the risk of price distortions, and increase overall transparency in the market. The cooperation of TERRE and IGCC platforms already shows significant improvements in efficiency and monetary savings. The introduction of MARI and PICASSO would allow European TSOs to better manage the resources and provide cost-effective energy services. All these platforms strengthen the European electricity market by bringing them closer to the target market design for balancing thereby increasing market integration and cost-efficient balancing services.

A summary of market design parameters was captured in the ENTSO-E Ancillary Services (AS) Survey 2020 and ACER Market Monitoring Report 2020, whose main results are shown in Annex A.

3.2.2 Non-Frequency Ancillary Services and Congestion Management Markets

Non-frequency ancillary service refers to 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 [28]. As mentioned in the introductory part of Section 3.2, based on focus of countries within OneNet demo clusters we limit our analysis to voltage control.

Further congestion refers to an overload of grid components, over and under-voltage and/or forced usage of the local fail-over capacity in the distribution system. Congestion management products could be used to defer grid investments or for operational use (e.g., redispatching). The Electricity Market Regulation and Directive support a market-based approach to procuring products for operational use [7]. The regulatory framework particularly ensures that distribution system operators can procure services from Flexibility Service Providers (FSPs) such as distributed generation, demand response or energy storage etc. via a market-based approach. Such an approach engages FSPs to provide the solution to cost-effectively alleviate the need to upgrade or replace electricity capacity and supports the efficient and secure operation of the distribution system. The market-based approach provides a low-cost alternative to grid reinforcements while also improving overall system efficiency. However, concerns about strategic behaviour and locational market power by market players have pushed several Member States to adopt a regulated method. The Active System Management (ASM) report prescribes that some general EU principles can be developed but the intrazonal congestion management process details should be established and implemented on a national level (ASMReport). With the growth of distributed generation, DSOs are beginning to have more congestion problems, causing countries to re-evaluate the market structure. This is where the new network code on demand response is an opportunity to materialize necessary coordination between TSOs and DSOs in order to unlock flexibility from distributed resources, so it can find the best value for consumers and the system, in this case related to the procurement of ancillary (both frequency and non-frequency) and congestion management related services.

In the joint scope of Task 3.2 and Task 3.4, a dedicated consultation moment in the form of two workshops was organized with all the country representatives within demo clusters: Northern, Eastern, Western and

Southern. One objective of the consultation moment was to better understand each country's approach to addressing congestion management and voltage control. The Table 3-1 below summarizes the current approach for the provision of flexibility aimed at addressing issues of congestion management and voltage control by various countries within the OneNet demo clusters.

Table 3-1 – Approach for provision of congestion management & voltage control services by various countries within OneNet clusters

Key Topic	Target model	Approach by various countries	OneNet Cluster Countries
Current approach for CM by TSOs	Market-based congestion management process	Use of energy part of the mFRR products for CM	Northern: FI, EE
		Bilateral agreements with customers/ Commitment of mu-run units at specific geographical locations	Northern: FI Southern: CY
		Central dispatch model	Eastern: PL
		Technical measures (grid reconfiguration, topology changes using switching breakers, emergency curtailment etc.)	Western: PT Southern: CY
		Day-ahead market bid for zonal redispatch	Southern: GR
		Use of limits in the planning process	Eastern: HU
		Tariff scheme/Dynamic grid tariff pilots	Eastern: SI
		No structural congestion at the moment and so congestion management is not addressed at the national level. However, with growing RES level congestion issues are foreseen to appear in future	Northern: LV, LT
		NA	CZ, ES, FR
Current approach for CM by DSOs	Market-based congestion management process	Use of energy part of the mFRR products for CM	Northern: FI
		Tariff scheme/Dynamic grid tariff pilots. The dynamic tariffing pilot projects use some of the dynamic charging possibilities of the network act, namely PKKT – positive critical peak tariff, and NKKT – negative critical peak tariff.	Eastern: CZ, SI
		Technical measures (grid reconfiguration, manually changing taps on distribution transformers or network improvement of lines, feeders and transformers, emergency curtailment)	Eastern: CZ, PL Western: PT, ES Southern: GR
		Network reinforcements	Western: ES Southern: GR
		Use of mobile resources such as generators or mobile substations. No standard business model and procurement process for DSOs to implement flexibility products to compete with traditional solutions	Western: ES
		Congestion issues whereby small-scale assets cannot connect to grid due to huge connection fees	EE

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		No structural congestion and so congestion management is not addressed at the national level	Northern: LV, LT
		NA	HU, FR
Current approach for VC by TSOs	Market-based voltage control process	Obligation for generators and storage at HV to participate in dynamic voltage control	Northern: FI
		Reactive power window (P-Q) for all connections is defined in the connection agreement	Northern: FI
		Bilateral agreements with individual providers/units	Eastern: CZ, PL LT
		Traditional assets of SO used for voltage control	Northern: LV, EE
		Annual auctions	Northern: LI
		Technical measures such as use of capacitor banks, shunt reactors and automatic tap changers for regulating reactive power in the transformers	Eastern: SI, PL, LT Western: PT Southern: CY, GR
		NA	HU, ES, FR
Current approach for VC by DSOs	Market-based voltage control process	Obligation for generators and storage at HV/MV to participate in dynamic voltage control (tap changer on HV/MV transformer working autonomously as well as with partial control by the dispatcher)	Eastern: SI
		Mandatory for units greater than 10 kW at LV to install smart PV inverter which can autonomously provide Q(U) and P(f) functions	Eastern: SI Southern: CY
		Technical measures such as use of capacitor banks, shunt reactors and automatic tap changers for regulating reactive power in the transformers	Western: PT, ES
		Annual auctions	Northern: LI
		NA	FI, EE, LV, CZ, PL, HU, FR, GR

In general, from the above table we see that there are no organized markets for CM and VC, but SOs use a combination of technical measures and other solutions. For example, central dispatch arrangements are used in some countries where TSOs determine the dispatch values based on the prices and technical parameters provided by resources as well as the whole network model. Then TSO constructs a schedule and issues instructions directly to resources. There is mostly no remuneration for counter actions due to the emergency character of the situation. The TSOs and DSOs in Finland and Estonia use mFRR bids for congestion management.

Outside OneNet clusters, Great Britain and Netherlands are the only countries where SOs commercially procure flexibility whereas in other countries several small, medium, and large-scale trials are being experimented with. DSOs in Great Britain routinely and ever-increasingly buy local flexibility services with the backing of favourable legislative requirements. All of the six DSOs in Great Britain procure flexibility with several launching marketplaces to boost participation [29]. TenneT which is the TSO in the Netherlands first performs cost-benefit-analysis (CBA) to assess grid needs. There are several reasons why market-based CM is

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implemented in the Netherlands such as if congestion is not severe or if the cost of congestion management is less than investing, or if the reinforcing of grids takes too long or seem infeasible [30], (SmartNet). Equigy is an independently operated market-intermediary platform in the Netherlands that integrates with existing TSO ancillary services markets and redispatch processes[7]. TenneT also implements a series of measures to prevent gaming (UKPN).

3.3 The need for coordination and integration

With the energy transition, an increasing number of flexibility resources will be connected to the distribution network. This would require all market stakeholders to adapt to new roles and responsibilities to manage the increasing complexity of the system. This is an opportunity to put in place the necessary coordination between TSOs and DSOs in order to unlock flexibility from the distribution grid so it can find the best value for consumers and the system, in this case related to the procurement of ancillary and congestion management and voltage control services.

In Section 3.1 the evolution of electricity markets in EU was presented, covering both existing and emerging markets. The goal of each of the existing markets is different, namely:

- The objective of wholesale markets such as day-ahead (DA) market is to primarily trade energy day-ahead.
- The objective of intra-day (ID) market is to adjust market participants' positions before real-time.
- The objective of the balancing capacity market is to reserve enough available capacity for future potential activation.
- Finally, the objective of balancing energy market is to ensure stabilization of frequency by trading energy.

All of these markets create multiple opportunities for market actors. Every FSP should be able to participate not only in balancing and wholesale markets but also to provide services for other system needs such as congestion management, voltage control and commercial applications such as peak shifting, portfolio optimization and peer to peer trading etc. At the same time, FSPs should be able to participate across different timeframes (from planning period of years ahead to near real-time). Until now, most emerging markets for congestion management and voltage control are not linked or integrated with the existing markets such as wholesale and balancing markets unless a central dispatch model is used [8]. To enhance the efficiency of markets

[7] Equigy is also referred to as Crowd Balancing Platform because it was a project composed of consortium members from Germany, The Netherlands, Italy, Austria and Switzerland.

[8] According to Article 2(18) of the Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing (Network Code on Electricity Balancing - NC EB) 'central dispatching model' is a scheduling and dispatching model where the generation schedules and consumption schedules as well as dispatching of power generating facilities and demand facilities, in reference to dispatchable facilities, are determined by a Transmission System Operator (TSO) within the integrated scheduling process.

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and exploit synergies when TSOs and DSOs procure flexibility, coordination between market processes and functions is essential.

Below we aim to establish objectives of sustainable market design, define coordination and integration, explain the drivers behind coordination and integration and also present categories of platforms showcasing market integration in practice.

3.3.1 Objectives of sustainable market design

The overall objective of WP3 is to design efficient, integrated, and scalable markets for the procurement of system services by DSOs and TSOs, with seamless coordination between DSOs and TSOs, DSOs and DSOs, and SOs and suppliers/aggregators/consumers/prosumers, and this within and cross-countries. To be able to design these types of markets, it is important to first understand what the overlying objectives of an efficient and sustainable market design are. Figure 3-2 provides an overview of these objectives.

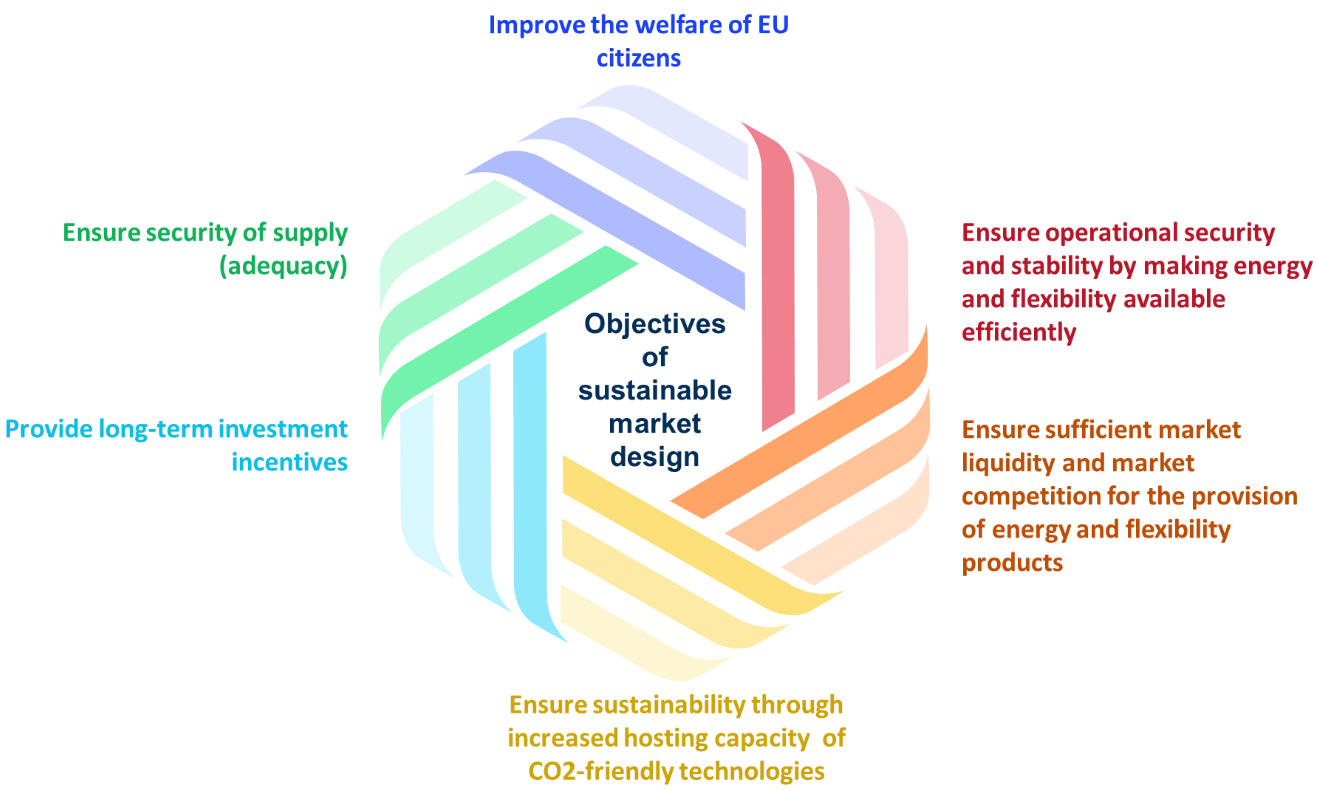

Figure 3-2: Objectives of sustainable market design

A total of six objectives were defined based on how sustainable market design is seen within the OneNet project. This vision is supported by high-level European policy and regulation documents, such as the Electricity Directive [7] and the Electricity Regulation [9]. Overall, by designing the market (for energy and flexibility) in a sustainable way, we ensure that adequate capacity is available in the long-term by providing investment incentives and, hence, also ensuring security of supply. Moreover, we also look at the shorter term, meaning

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that we make sure that energy and flexibility are made available in an efficient way (through markets) and that those markets are sufficiently liquid and cater for sufficient competition. An important aspect that cannot be forgotten is that, by designing energy and flexibility markets in a sustainable and efficient way, we can increase the market penetration of RES and hence assist in reducing CO_2 emissions. Finally, all of these aspects result in an increase in welfare of EU citizens by lowering energy prices, valuing flexibility, improving environmental sustainability and ensuring security of energy supply.

One way to ensure that energy and flexibility are made available in an efficient way, is through the integration and coordination of markets. In the next section, we will go into integrated and coordinated markets in more detail and look at their objectives.

3.3.2 Objectives of coordinated and integrated markets

In OneNet, we define coordination as 'all aspects related to processes between market actors', and integration as 'all aspects related to equal market access of technologies, flexible sources and market participants'. For both coordinated markets (coordination) and integrated markets (integration), a number of objectives can be defined.

Figure 3-3 below presents an overview of the objectives of coordinated and integrated markets.

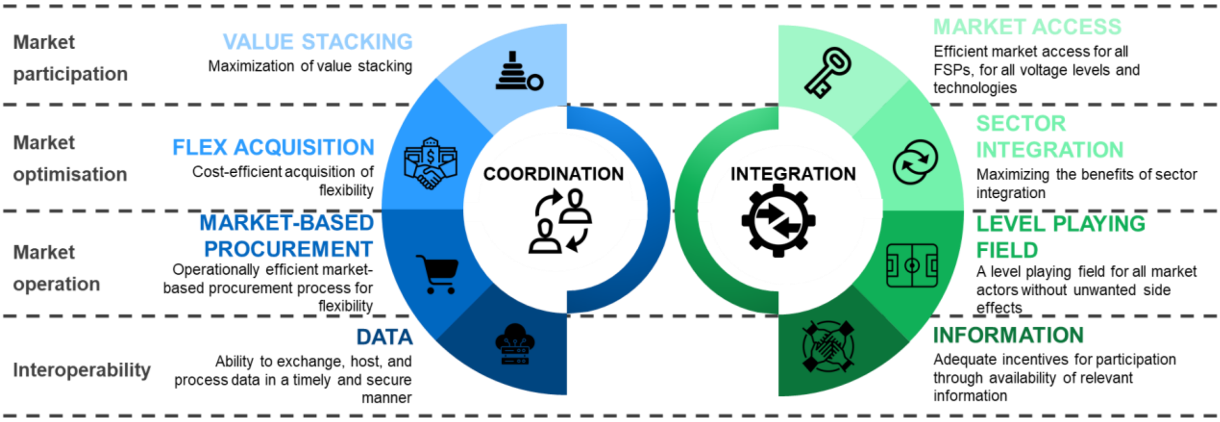

Figure 3-3: Objectives of coordinated and integrated markets

We define four objectives of coordinated and integrated markets each. A first objective of coordinated markets is the maximization of value stacking. This means that it is possible for an FSP to participate, with the same asset/capacity, in different energy and flexibility markets simultaneously or sequentially. Value stacking decreases the overall system cost and brings more flexibility to the system. A second objective is cost-efficient acquisition of flexibility. This can be looked at either from the point of view of the individual SO, or from the system perspective. Regarding the perspective of the individual SO, flexibility can be acquired through implicit (e.g., tariffs) and explicit (e.g., markets) mechanisms. Cost-efficient acquisition can hence be attained by using the implicit or explicit mechanism, or a combination of both, depending on the situation. Regarding the system

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perspective, several coordination models and resulting rules for flexibility allocation exist, e.g., the SmartNet project [31] [31], the CoordiNet project [32]. More specifically, the CoordiNet project found that a common market model can provide higher procurement efficiency from an optimization standpoint, as the common market pools all resources and purchases the bids that can most optimally meet all the participating SOs' needs [33]. Hence, if the rules for priority/exclusivity diverge from the optimal resource allocation, the cost efficiency will also be lower. A third objective is an operationally efficient market procurement process for flexibility. This objective is related to cross-border coordination (i.e., PICASSO, MARI, TERRE), joint procurement of system services by TSOs and DSOs, alignment between different markets in market processes (i.e., prequalification, procurement, activation, monitoring and settlement (baseline) process) and alignment in methodologies for network representation. The fourth objective of coordinated markets is the ability to exchange, host, and process data in a timely and secure manner as the types of coordination mentioned above cannot take place without data.

Then, the first objective of integrated markets is efficient market access for all FSPs, across all voltage levels and for all technologies. This could, for instance, relate to a uniform access and registration process/platform for assets willing to participate to flexibility markets. Moreover, currently it is still difficult for low voltage assets to participate in markets. Participation should also be technology-agnostic. A second objective is an equal level playing field for all market actors without unwanted side effects. This refers to the risk of gaming or strategic behaviour in certain market set-ups. A third objective is to maximize the benefits of sector integration where the different energy carriers are aligned in different market processes. A fourth and final objective is the presence of adequate incentives for market participation through the availability of relevant information such as anticipated flexibility needs, prices and expected revenues.

3.3.3 Drivers for coordination and integration

There are many benefits to integration and coordination of markets, and it serves various goals (cost efficiency, maximization of welfare, increased reliability) as explained in Section 3.3.2 above. In markets with high degrees of fragmentation, generators can use their market power to raise prices or withhold capacity. Furthermore, increasing the number of participating DERs can be an important improvement; however, it would still be insufficient in case network congestions are easily predictable. And so, a cost-efficient market increases the competition and reduces market concentration leading to competitive prices for consumers. On the other hand, fragmented markets become more expensive in the long-term and they do not promote interoperability across products and services. Below we describe various drivers which highlight the relevance of coordination and integration of various markets [9].

[9] This is an illustration of various drivers, but the list is not exhaustive.

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3.3.3.1 Skewed distribution of the generation in-feed

More recently, the integration of renewables has been an important factor that drives cross-border cooperation. All European countries rely on different electricity resources. For example, France is dominated by nuclear energy, Germany has still a significant share of coal, while the UK, Spain, and Italy have relatively more gas in their electricity mix than other European countries. Norway has significant hydro capacity [34], [35]. This indicates that there is considerable room for cross-border trading, especially within day-ahead and intra-day timeframes, to make the most out of price discrepancies between different generation mixes across EU member countries. The differences in renewable generation can be exploited to solve congestion management and other emergency situations. Extreme windy days can lead to power flow surpluses from wind parks which can overwhelm the power grid in one country and non-sunny days could cause shortages in another country. The higher the share of RES in the energy mix, the greater the need for coordination and integration.

3.3.3.2 Technical scarcities (stabilizing the grid, ensuring security of supply, managing increasing congestion)

For the European interconnected system to properly function, the frequency cannot go below 47.6 and above 52.4 Hz. At the extreme values of 47.5 (under frequency) and 52.5 Hz (over frequency) all connected generation and consuming devices would automatically disconnect [36]. Transmission System Operators (TSOs) are increasingly facing issues related to volatility in frequency due to the decrease in the total level of system inertia. This is driven by the fact that conventional synchronous power generating modules are being replaced by power electronic interfaced sources such as wind and solar. This further leads to bigger and faster frequency oscillations from safety values making oscillations less controllable. As per ENTSO-E TYNDP scenarios for 2030 and 2040, with higher integration of RES and more distributed generation, inertia in all of the synchronous areas will decrease [37].

The unexpected incident of peak demand or unplanned and simultaneous outage of several power plants, e.g. due to extreme weather events and a lack of renewable or conventional fossil resource availability, could endanger the security of supply. Without a proper market framework (e.g. incentives to keep existing and build new renewables capacity), resource adequacy issues could appear. This is especially true when traditional dispatchable power plants are phased out. This will further require stronger coordination between system operators, regulators, and market operators.

With the share of variable renewable energy resources (RES) increasing, the physical congestion on the network is also increasing. As per an ACER/CEER report, the total cost of remedial actions to relieve physical congestions totalled 2.25 billion euros in 2019 [38]. Germany accounted for nearly 50% of the overall costs with more than 1.1 billion euros spent on remedial actions. These costs of congestion management are passed on to consumers in the form of higher grid tariffs. It is therefore important to implement solutions and methodologies

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that improve congestion management across borders (for example, grid reinforcements, optimal bidding zones configurations, common set of market rules, trading closer to real-time delivery across borders including the possibility of unit commitment rescheduling or stronger locational signals in tariffs or market products).

The shift to decentralized generation such as small-scale wind and solar photovoltaic, is affecting Distribution System Operators (DSOs) also and, in some cases, creating problems such as overloading of feeders and voltage oscillations, that have become more and more common. High feed-in from wind and other renewable generators, connected to parts of the networks, which were not originally planned to accommodate large generation infeed, has led to higher redispatch costs for network operators. In several areas, major grid reinforcements are planned or under construction, but take a long-lead-time to be completed[10].

Since the pace of grid development may lag the deployment of DERs, it calls for effective and collaborative congestion management solutions by TSOs and DSOs, facilitating the provision of flexibility and avoiding the curtailment of renewable energy production.

3.3.3.3 Ensuring optimal use of flexibility resources

According to a publication 'Connecting the dots: Distribution grid investment to power the energy transition' by Eurelectric, more than 70% of new renewables will be connected to the distribution system of low and medium-voltage grids (e.g., rooftop solar) [39]. In addition to this, electrification of end-user energy demand through electric vehicles and electric heat pumps implies that a high number of resources will be connected to distribution networks. According to the ENTSO-E TYNDP 2020 scenarios report, about 30 to 118 million electric vehicles and about 40 to 45 million heat pumps could be connected to the electricity grid by 2030 [40]. This raises specific operational challenges such as:

- Complexities in forecasting, observability, controllability.
- Coordinated access to resources between TSO and DSO for sourcing ancillary and non-ancillary services.
- Coordination at regional level to ensure synergies between flexibility portfolios across borders.
- Increased interdependencies across sectors, mean that the optimal use of resources should also be ensured beyond the electricity grid.

[10] The recent publication 'Connecting the dots: Distribution grid investment to power the energy transition' states that 375-425 billion euros of investments in the power distribution grids will be needed in EU27+UK in 2020-2030 to achieve the EU environmental objectives in areas such as modernization, digitalization, electrification of buildings and industry resilience. It highlights that the investment in the distribution grid is necessary to avoid obsolescence and ensure the replacement of ageing equipment. This allows for a network compatible with new digital assets (e.g. digitalised switchgear) that enhance distribution grid observability and enable key flexibility services.

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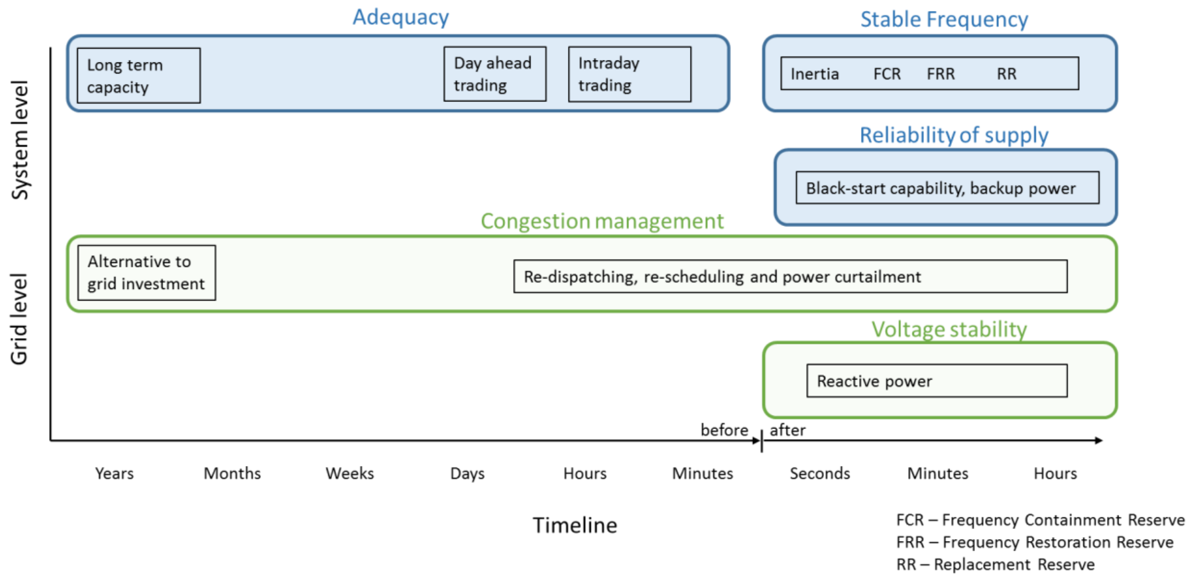

Figure 3-4: Flexibility needs in the dimensions of space and time from ISGAN report on 'Flexibility needs in the future of power system'.

All these resources could potentially contribute to flexibility ensuring stability and security. Figure 3-4 below from the ISGAN report on "Flexibility needs in the future of power system" outlines the categorization of flexibility needs in the dimensions of space and time [41] and shows that flexibility required at the grid and system level could vary in timescale from seconds to minutes and hours and beyond[11]. System flexibility here means maintaining stable frequency and securing balance in all the energy flows. And grid flexibility means maintaining voltages and transfer capacities within threshold limits.

To unlock the potential of this flexibility, coordinated market processes and standardised data exchanges between various stakeholders will be required. Proper coordination between TSOs, DSOs and FSPs is required since the DERs can provide services to tackle location-dependent problems such as congestions but also, if properly aggregated, for supporting the traditional flexibility needs such as balancing and portfolio optimisation.

Chapter VI of Regulation 2019/943 of 5th June 2019 calls for close coordination between TSOs and DSOs and is being realised through several ongoing initiatives such as the BRIDGE Initiative, EU Smart Grid Task Force, the ENTSO-E Research, Demonstration, and Innovation Roadmap 2020-2030, and several pilot projects and market initiatives in which TSOs and DSOs cooperate for the procurement of flexibility from DER (Gopacs, Enera, Interrface, Nodes, etc.) [9], [42]. The purpose of flexibility coordination and integration is to make sure that the allocative efficiency of flexibility used for different purposes is maximized and at the same time, flexibility trading by one market party does not create negative effects for other market parties.

[11] The figure does not consider the long-term analysis of voltage stability and as a consequence is not able to predict the scarcity of reactive power and need for investments.

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3.3.3.4 Address partial grid alienation

Today, Europe has around 3500 renewable energy cooperatives as per the findings of EU-funded project MECISE [43]. Furthermore, an Europe-wide inventory of citizen-led energy initiatives and projects showcases over 10,000 initiatives in 29 countries [44]. These renewable energy cooperatives and citizen-led energy initiatives are driven by the need for self-sufficiency and desire to be energy independent but are still expected to rely on the grid as a back-up. As the cost of renewable generation declines, these decentralized local models could become more and more attractive and increase the complexity of system operations. Increased number of prosumers, renewable energy cooperatives and aggregators responsible for optimizing behind the meter assets will no longer be dependent on net kWh purchases from the grid – in fact some may become net exporters. In such case, the important service of the network will not be providing energy, but rather ensuring backup service in addition to balancing services, voltage and frequency support and power quality. Thus, flexibility solutions are very important since the nature of transactions can vary from a more horizontal arrangement (e.g., dynamic pricing) to more vertical arrangement (e.g., local aggregator or market-based flexibility procurement by DSOs).

The future power system and grid must be able to respond to all the above drivers and associated challenges. Flexibility and integrated markets are key to maximising the use of existing infrastructure to enable secure, reliable, and cost-effective development of the future transmission/distribution grid.

3.3.4 Market integration and coordination in practice

The definitions for integration and coordination were defined in Section 3.3.2. In this section, we look at various initiatives and projects on information sharing between TSOs and DSOs being trialled and implemented all over Europe today. The objective of introducing this section is to showcase how real-life projects showcase effective integration and coordination between TSOs and DSOs by supporting sharing of tools and competencies. The projects are the result of either TSO innovation projects or initiatives independently led by DSOs along with third parties such as technology developers, power exchanges and energy suppliers. ENTSO-E's review of existing flexibility projects has identified three categories of projects: Aggregators, Data exchange platforms and flexibility platforms [45]. Data exchange platforms facilitate the exchange of grid, market or meter information between various entities across the energy supply chain. However, these platforms themselves do not support market-based procurement or administration of dispatch of energy or system services. Flexibility platforms are the digital platforms that facilitate or coordinate the procurement, trade, dispatch and / or settlement of energy or system services. These include both local flexibility platforms which resolve constraints on the DSO network as well as balancing platforms (e.g. TERRE). Furthermore, flexibility platforms are categorized based on their operational models:

1. Flexibility platforms as administrative flexibility coordinators

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2. Flexibility platforms as self-contained marketplaces
3. Flexibility platforms as market intermediaries

3.3.4.1 Flexibility platforms as administrative flexibility scheme coordinators

In an administrative flexibility scheme, coordinators provide support for a centralised cost-based allocation of flexibility (and not market-based allocation of flexibility), by facilitating data exchange between relevant stakeholders. DA/RE is one such example of a platform that facilitates coordination between TSOs, DSOs, generating units and storage units in Germany[12].

3.3.4.2 Flexibility platforms as self-contained marketplaces

Today there are some self-contained marketplaces (e.g. PicloFlex) for congestion management that enable flexibility to be exchanged between FSPs and DSOs, across both time and location dimensions. Self-contained marketplaces relate to the flexibility platform which performs essential functions of a marketplace such as running auctions, clearing transactions and settling payments between system operators (SOs) and Flexibility Service Providers (FSPs). Such marketplaces are less mature compared to competitive wholesale and balancing markets. Self-contained marketplaces include more local-dimension specificities in their products, and so it will be more challenging to integrate them.

Self-contained local markets are better able to respond to variations in local system needs, improve access for DSOs and provide faster responses to network congestions. They also provide the opportunity for the market to reveal the product design that works better for users through innovation rather than stalling it through standardization and regulation.

However, the existence of wholesale and flexibility markets in parallel may present arbitrage opportunities, for example, generation schedules of plants are first increased in the wholesale market and then reduced on the flexibility market which may lead to potential gaming possibilities. In addition, fragmented local markets with smaller bidding zones may create liquidity problems and require an increased level of coordination across markets to manage imbalances created by activation.

[12] Test partners for DA/RE platform are: EnBW Ostwuerttemberg DonauRies, Regionalnetze Linzgau, ED Netze, FairNetz, bnNetze, MVV Netze, Stadtwerke Schwäbisch Gmünd, Stadtwerke Karlsruhe Netzservice, Stadtwerke Heidelberg and EGT Energie.

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3.3.4.3 Flexibility platforms as market intermediaries

Market intermediaries are the types of platforms that facilitate penetration of DERs into existing wholesale energy and balancing markets (e.g. Nodes or Equigy platform[13,14]) or act as a single gateway for SOs to procure flexibility through established wholesale energy and balancing markets (e.g., GOPACS)[15]. Market intermediaries facilitate the exchange of standardized balancing and congestion management products. Within the INTERRFACE project, Interoperable pan-European Grid Services Architecture (IEGSA) aims to facilitate competition between energy markets by linking wholesale, retail, balancing and new congestion management markets [46].

Intermediary markets will increase the number of market parties that effectively compete in wholesale and balancing markets: either by simply increasing the size of the market or by encouraging cross-entry between neighbouring member states, thereby unlocking new business cases that would not have been possible in a smaller market.

A major difference observed is that self-contained marketplaces act as markets for congestion management and market intermediaries act as integrators to existing wholesale and balancing markets. Market intermediaries could play a key role in achieving an efficient overall allocation of flexibility.

[13] NODES-IntraFlex, NODES- NorFlex and Piclo Flex are currently only used by DSOs to procure flexibility for congestion management purposes.

[14] Founded by an international consortium of TSOs, Equigy is an independently operated market-intermediary platform that integrates with existing TSO ancillary services markets and redispatch processes.

[15] GOPACS is the sole congestion management platform for all congestion related actions from DSOs and the TSO in The Netherlands.

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4 Barriers to fully coordinated and integrated markets

This chapter provides an overview of the barriers to fully coordinated and integrated markets. Figure 4-1 below explains the inter-relations between sub-chapters. First a list of initial theoretical barriers is presented in Section 4.1. Second, a gap-analysis is performed by presenting initial list of theoretical barriers to demo clusters and we obtain feedback on the relevance of each barrier to the country of operation in Section 4.2. Finally, the initial list of barriers is complemented with additional barriers identified based on external discussions and also recently published ACER Framework Guideline on Demand Response (DRFG) [4]. The entire list is subsequently mapped with objectives of coordinated and integrated markets identified in Section 3.3.2 and is presented in Section 4.3.

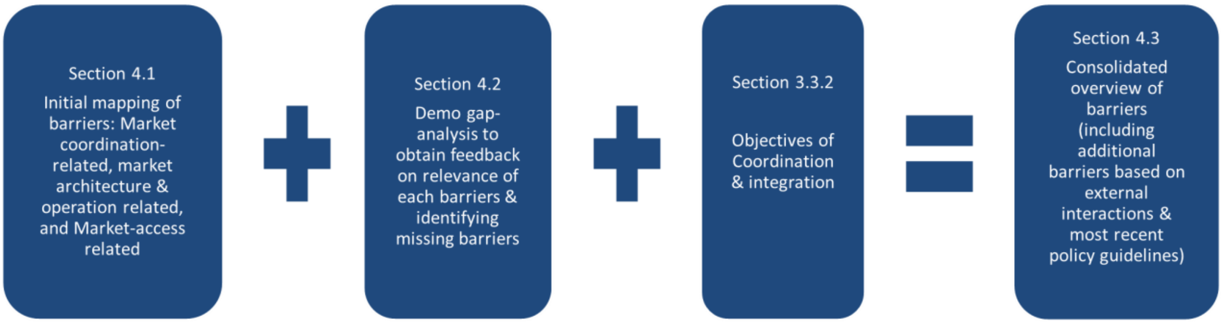

Figure 4-1: Interlinkages between sub-chapters towards consolidated overview of barriers

There are various reasons why most of the units that are connected to the distribution grid do not yet participate in providing re-dispatching services to TSOs, except for some combined heat and power (CHP) units or large electric boilers [47], [48]. Some of the constraints on the effective participation of distribution connected DERs may include the lack of explicit agreement or coordination with local network operators, product design and other technical constraints (such as the response time, required real-time measurement and accordance with the minimum bid size), and in some cases the absence of a regulatory aggregator framework at the national level. In this section, we intend to dig deeper into various limitations to the coordination and integration of markets. The list of initial theoretical barriers investigated in this section is based on several publications including the joint report “Roadmap on the evolution of regulatory framework for distributed flexibility” by ENTSO-E and European associations representing DSOs, and the EU Smart Grids Task Force report on demand side flexibility, challenges described in ONENET deliverable 3.1 “Overview of market designs” and academic material at large [49], [26], [63].

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4.1 Theoretical barriers to coordinated & integrated markets

Below various theoretical barriers are classified into three categories: market coordination, market architecture and operation, and market access and aggregation related barriers. Each barrier is explained further in detail as follows.

4.1.1 Market coordination related barriers

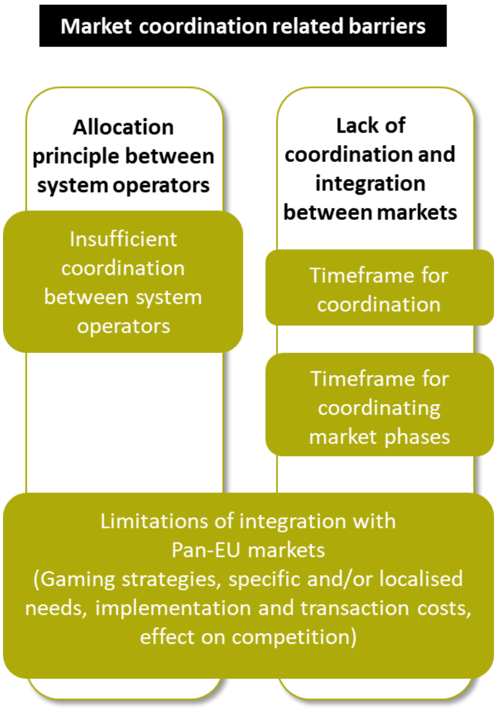

Figure 4-2: Various market coordination related barriers

4.1.1.1 Lack of coordination and integration between markets

Timeframe for market coordination

The clearing of the energy and ancillary services markets happen simultaneously in the USA, whereas in Europe it works as a sequential clearing. Currently, the most frequently used option in European balancing markets is the sequential clearing of capacity and energy bids (generally, even if bidders are not awarded with their balancing capacity bids, they still have a chance to submit balancing energy bids). The sequencing order of markets is dependent on many variables such as the bidding frequency, how often a specific auction takes place, the bidding period, the timeframe between gate opening and closing times and the frequency of market clearing.

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Market gate opening and gate closure times (GCT) play an important role in determining whether FSPs that were not awarded in the balancing capacity market can still offer their energy in one of the spot markets. Timeframes for markets, especially gate closure times (GCT) and resolution of trading products also affect the market efficiency. GCT being too far away from the delivery period could cause large forecast errors, increasing overall system demand in subsequent markets. Similarly, hourly resolution in DA cannot accurately reflect the supply and demand dynamics, especially for RES whose variability can be significant on a sub-hour basis [50]. For example, the current GCT of day-ahead market is typically 12:00 PM day-ahead. It is criticized for being too far from the delivery period (ideally it should be no more than 15min between GCT and the delivery period) [51]. The lead time of 36 h for the last hour of the following day could cause large forecast errors, putting RES generators into an imbalanced position close to the delivery period and increasing overall system demand for balancing in ID and balancing markets [49]. The time resolution of trading products could also affect market efficiency.

Integration of emerging markets with existing market

Lack of integration between emerging and existing markets either via information sharing, agreeing on common protocols, or timely retrieval and processing of data across different operating systems is also one of the major barriers to efficiently allocating flexibility. As explained in Section 3.3.4, Intermediary markets (a type of flexibility operating model) increase the number of market parties that effectively compete in wholesale and balancing markets: either by increasing the size of the market or by encouraging cross-entry between neighbouring member states, thereby unlocking new business cases that would not have been possible in a smaller market.

Timeframe for coordinating the market phases (order of sequential market framework from prequalification phase to settlement)

Insufficient coordination of flexibility markets with existing markets especially in the market phases such as prequalification, procurement, activation, settlement etc. could also lead to overlapping time windows between market phases, causing conflicts or undesired effects.

4.1.1.2 Allocation principle of resources between system operators

In the near future, flexibility can be used to provide value not only from an overall system perspective (stability, frequency, and energy supply) but also from a local perspective (transfer capacity, voltage, and power quality). For both system and local/grid-level, coordination between TSOs and DSOs will be important. However, in certain cases, when common markets are used, neither priority nor exclusivity are pre-defined.

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Insufficient coordination between system operators

One single asset, if appropriately pre-qualified, might be able to provide flexibility for congestion management in the DSO grid, for congestion management in the TSO grid or for balancing performed by the TSO. Therefore, there is a need to ensure coherence between all congestion management and balancing bids. For system operators to communicate their needs in different timeframes, proper interaction is required between two Merit Order Lists (MOLs) to avoid double activation of the same asset and ensure the secure operation of grids by performing coordinated grid impact assessments.

The flexibility activation scenarios causing various types of conflicts between TSO and DSO are outlined in Table 4-1 below. This table is an adaptation based on the IEEE PES paper “identifying TSO-DSO conflicts when acquiring ancillary services from electric vehicles”[52].

Table 4-1: TSO-DSO conflict scenarios for flexibility

#	Scenarios	Regulation Type for TSO	Regulation Type for DSO	Problem	Type of Conflict	Solution
1	Flex activation solves problems for both TSO and DSO	Up (Gen ↑ and Load ↓)	Up (Gen ↑ and Load ↓)	NA	Remuneration	Optimal scheduling
2	Flex activation solves problems for both TSO and DSO	Down (Gen ↓ and Load ↑)	Down (Gen ↓ and Load ↑)	NA	Remuneration	Optimal scheduling
3	Flex activation satisfies the needs of TSO but causes a problem for DSO	Down (Gen ↓ and Load ↑)	Up (Gen ↑ and Load ↓)	Distribution overload (Exceeding capacity limits of components)	Technical	Prioritization Or Cancellation of unfavourable bid based on grid-impact assessment
4	Flex activation satisfies the needs of TSO but causes a problem for DSO	Up (Gen ↑ and Load ↓)	Down (Gen ↓ and Load ↑)	Distribution overload (Exceeding capacity limits of components)	Technical	Prioritization Or Cancellation of unfavourable bid based on grid-impact assessment
5	Flex activation satisfies the needs of DSO but causes a	Down (Gen ↓ and Load ↑)	Up (Gen ↑ and Load ↓)	System imbalance or Transmission overload (exceeding thermal limits)	Technical	Compensate imbalances or Prioritization

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	problem for TSO					
6	Flex activation satisfies the needs of DSO but causes a problem for TSO	Up (Gen ↑ and Load ↓)	Down (Gen ↓ and Load ↑)	System imbalance or Transmission overload (exceeding thermal limits)	Technical	Compensate imbalances or Prioritization

Scenarios 1 and 2 occur when a resource can satisfy the needs of both TSO and DSO. However, the offered flexibility may not necessarily be enough to satisfy the needs of both TSO and DSO. The type of conflict identified here is related to remuneration, since one flexible resource can satisfy multiple needs. Hence, it is important to define a fair way to remunerate the flexible resource (e.g. identifying which service the resource is remunerated for, and determining whether it is fair for the price to be the same even though required performances are different). The solution could aim at optimally allocating flexibility products both from an economic and technical point of view.

Scenarios 3 and 4 occur when the TSO uses resources from the distribution grid. If this service is mainly organized without any involvement of the DSO, it potentially could lead to problems in case of increasing volumes. For example, balancing activations executed by a TSO can reduce the quality of service due to power line congestions, voltage constraints or overloading of the power transformer at the TSO/DSO border. As a result, affected DSOs could be informed about the relevant trades in the balancing market and their approval could be requested before activation. This would result in DSOs validating flexibility resources to avoid constraints in the distribution system [16]. Similarly, trade for congestion relief of a DSO's feeder should not contribute to congestion in the network of another involved DSO due to counter trading. Therefore, at least all the affected parties of an ongoing trade should be informed before trade finalization. Since the type of conflict explained above has a technical nature, the solution is to have either a) prioritization rules or b) cancellation of unfavourable bids based on grid-impact assessment and communicating the outcome to involved stakeholders or c) efficient overall allocation of flexibility via the common market framework.

Scenarios 5 and 6 occur when a DSO activates flexibility to solve a local problem in a particular area. It may lead to a problem at a system level in terms of balancing. In balanced operating conditions, a decrease of consumption to prevent congestion at distribution level could force the BRP to increase the consumption elsewhere or cause a system imbalance. Like scenarios 3 and 4 above, the conflict has a technical nature, and the solution is to have either a) prioritization rules or b) cancellation of unfavourable bid based on grid-impact

[16] In addition to this, other option could be the coordination between TSO-DSO at the interconnect point (Substation level), and the acting as a proxy for the selection of resources for cm and voltage control. This has already been implemented in some countries and subject to research.

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assessment and communicating the outcome to involved stakeholders or c) efficient overall allocation of flexibility via the common market framework.

4.1.1.3 Limitations or side-effects of integration with existing Pan-EU markets

Possibility of gaming strategies when combining two or more markets

a) The possibility for market parties to trade sequentially in different market timeframes can lead to strategic bidding and thus maximize the trading profits of certain bidders. Such bidding behaviour is not per se necessarily harmful nor illicit, but in some cases – especially for markets with strong locational aspects - can lead to market inefficiencies or even to abuse of market power. For example, if market participants can predict the outcome of the market and of network congestions, they can adapt their strategy within the wholesale, balancing and/or congestion management markets. The gaming risks appear particularly evident when combining zonal wholesale markets with redispatch markets (which are by definition locational – i.e. nodal). This different geographical granularity of the two markets, and hence the different pricing mechanisms, can lead to the so-called "Inc-dec gaming"; a bidding behavior used for instance by Enron during the 2000 Electricity Crisis in California. As in many zonal markets, network congestions are recurrent and predictable, and generators can anticipate higher profits by selling their production on the congestion management market rather than the wholesale market (or vice versa). Generators in the scarcity area offer their energy at higher prices in the wholesale market, remaining out of the merit order curve but knowing they will sell their power at such prices in the redispatch market, as they will be selected by the system operators for upward-redispatch to relieve the network congestions. Generators in the export-congested area apply an opposite strategy knowing they can buy back energy at lower prices in the redispatch market when they will be redispatched-downward. Such gaming behaviour leads to even higher congestion, windfall profits for generators, and ultimately higher costs for society. These risks have also been identified by European Regulators [53].
b) These gaming risks can be mitigated by different regulatory or market design measures. Increasing the number of participating resources in the market – which should be the case in the future thanks to distributed energy resources – can be an important improvement; however, it would still be insufficient in case network congestions are easily predictable. In fact, as demonstrated by L. Hirth et al. [54] gaming strategies can occur even with perfect competition, thus market power would only be an aggravating factor. Alternatively, market power mitigation techniques - as used by US ISOs - could be introduced to impose cost-based bidding on assets which, for their specific location and nature, could exercise market power if they were allowed to bid-freely in redispatch markets. Lastly, while this would require important changes, a nodal market design would ensure consistent geographical granularity across all market timeframes, preventing such gaming risks.

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Effects of competition and liquidity

To promote competition and new services in the European electricity market, market participants must be able to offer their services in all markets. And thus, liquidity is an essential element of a well-functioning market delivering effective pricing, reducing fragmentation, and enabling FSPs to provide their services where they bring the most value to the system. The synergies that could result from market coordination and integration of markets could bring improved efficiency. Interoperability of diverse market processes is a bare minimum requirement for an integrated system's approach. It is necessary to consider the various timeframes for various markets and the potential stacking of these services. This will not only prevent lock-in so that FSPs can access alternative revenue streams, but it will also boost market liquidity.

The long-term view of system operators is that congestion should be solved through a market-based allocation of flexibility services (voluntary or mandatory bidding, possibly in combination with cost-based regulation when considered appropriate by the Regulator) where technically feasible and cost-efficient. However, such competition and liquidity can be limited by the specific location of grid constraints and related necessary flexibility assets to relieve such congestion. In some cases, there cannot be a multitude of FSPs to create a market with competitive bidding. It becomes more difficult for TSOs and DSOs to find FSPs as counterparties if markets have low liquidity and consequently this may lead to inefficient prices as well as higher risks of market power abuse.

4.1.2 Market Architecture and Operation related barriers

Figure 4-3: Various barriers related to Market architecture & operation.

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4.1.2.1 Products & services

Most of the following barriers within this section have been identified within the scope of the Joint TSO-DSO taskforce on distributed flexibility [26].

a) **Harmonized products**: currently the only characteristics for products defined at the EU level are day-ahead, intraday, and standard balancing products. High-level principles of harmonization have been defined in OneNet deliverable D2.2 for congestion management and voltage control to get sufficient alignment with balancing and wholesale markets which aim to reduce barriers for market parties who wants to provide flexibility in different EU markets [55].

b) **Pre-qualification requirements**: When it comes to prequalification methods, the technology and performance requirements vary across EU markets and timeframes. At the moment, the product pre-qualification process is regulated at EU-level for TSO balancing services only and partly for voltage control services. The lack of alignment of the product prequalification process, while guaranteeing coordination between system operators, and while justified in some cases, leads to multiple prequalification processes which can limit the integration of markets. Having some harmonization principles in line with balancing product pre-qualification requirements may alleviate this barrier. There is a need to harmonise/standardise access to pre-qualification requirements related data (e.g., location, duration, ramp rate etc.) from different system operators which could in turn lower the entry barriers, increase the liquidity of markets and thus contribute to market integration and development of flexibility service providers. However, the national specificities such as the differences in generation mix, market design, network etc. could make the prequalification process difficult to harmonize even if the products are harmonised. In addition to this, there is no specific guidance or legislation regarding a framework for grid prequalification of congestion management service providers.

c) **Harmonized rules for baselining**: The baseline calculation methodology (baseline based on averaging of recent historical load data or regression considering several factors such as weather, load behaviour, system demand or comparable day methods etc.) is different from country to country and also within a country depending on the products and services provided. There is however a lack of a common standard for the data to be used to facilitate the interoperability of solutions from one baseline calculation methodology to the other. Verification of activated flexibility requires accurate measurement and the exchange of data for settlement purposes. Lack of alignment in the technical specifications of submeters (data parameters, standard data formats, communication protocols, data quality etc.) could increase complexities when it comes to participation in the provision of flexibility services. Requirements for sub-meter data validation should ensure the quality and granularity of sub-meter data. Coordinating large scale behaviour of small units (and underlying IT communication systems) is also quite complex.

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d) **Harmonized rules for activation and settlement**: The activation of all the flexibility services should be coordinated and prioritized between TSO and DSO to avoid unintended effects. Settlement of flexibility services other than for balancing energy is not addressed in the existing regulation. Furthermore, data required for settlement should be by default required in disaggregated per service provider unit or group. This is important in order to allow aggregation models to work properly. A coordinated settlement approach between system operators, even if platforms are separated, could improve value stacking potential. Here as well some general EU principles could facilitate the development of consistent market designs across the EU. Lack of harmonization of data exchange principles for settlement may increase the risk of market fragmentation, leading to varied rules and organizational setups across member states.

4.1.2.2 No definition for the role of Market Operator (MO) for flexibility services

European regulation introduced the role of Nominated Electricity Market Operator "NEMO" for power exchange organizing cross-zonal trade in the wholesale energy markets (DA and ID), while in ancillary service markets, TSOs are the natural market operators, either individually at the national level or jointly for the EU balancing platforms such as MARI, PICASSO and TERRE.

Whether the MO for flexibility services should be regulated - and if so, how? - and its interaction with other market operators is not defined. Options for the market operator include a network operator (DSO or TSO), a group of operators, an independent market operator (IMO) or a third party. This aspect, while relevant in general terms, may not necessarily impact the degree of efficiency and market openness of flexibility markets. At this point in time, EU framework guideline on demand response (FGDR) foresees the rules on this topic to be further executed since the market for distributed flexibility is still developing and too detailed regulation on this topic may hamper innovation. Having said this, it would be beneficial for FSPs and Market Operators if the interface between TSO/DSO and the Market Operator and the one between Market Operator and FSPs were to consider the standardization of some elements of the trading interface.

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4.1.3 Market access and rules for aggregation related barriers

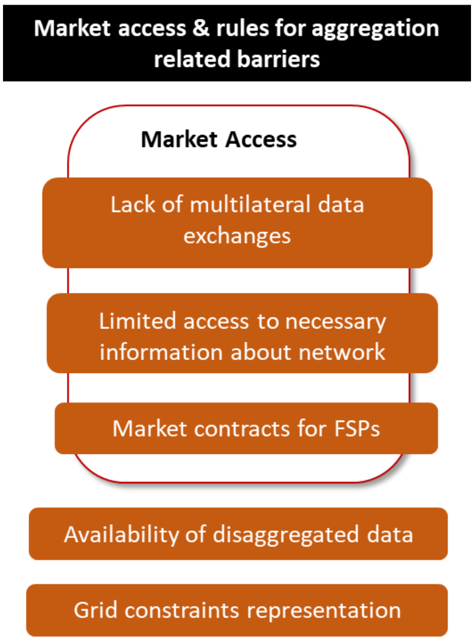

Figure 4-4: Various barriers related to market access & rules for aggregation.

4.1.3.1 Lack of multilateral data exchanges between TSOs/DSOs/FSPs/3rd Party

In the near future, with new processes and interactions between decentralized assets such as electric vehicles, heat pumps, solar PVs etc., the market parties who control such assets and between TSOs and DSOs need to be developed and strengthened. For example, to enable market-based congestion management, secure and easy exchange of bids, location, measurements etc. should take place. A lack of harmonized processes and interactions could lead to fragmented solutions which could be more costly in the long-term, threatening the interoperability between products. Key Organisational Requirements, Roles, and Responsibilities (KORRR) is a pan-EU proposal developed by TSOs that establishes requirements for coordinated processes/functions between system operators [56]. Implementation of SOGL data exchange requirements and the KORRR methodology could ensure that both TSOs and DSOs obtain necessary data for performing grid assessment. Scattered exchange of real-time, scheduled, forecast, and structural data between TSOs, DSOs and SGUs could also pose a threat to interoperability and so a consistent EU data exchange framework based on SOGL and KORRR is important. Here FGDR provides for a national single tool/interface for the registration and prequalification of providers and units to all the services.

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4.1.3.2 Limited access to necessary information from system operators about needs for network services

Market parties should have necessary information about the needs for network services, e.g. requests from system operators for flexibility services, location of congested grid area, rules for organizing the market – roles, participants, the technical requirements such as approved capacity limits, duration, ramp rate etc., including the determination of settlement prices, rules for measuring performance, conditions and manner of use of services by operators. If the necessary information is not published and the access to different data from different system operators is not harmonized, then it would impact market integration.

4.1.3.3 Market contracts for FSPs

The Directive (EU) 2019/944 defines an independent aggregator as a "market participant engaged in aggregation who is not affiliated to the customer's supplier" [7]. Various roles can be performed by FSPs. FSPs can help TSOs by offering balancing services, DSOs to manage their local constraints and finally engage with DERs and customers, thus unlocking commercial applications such as portfolio optimization, peak shifting, and peer-to-peer trading etc.

If technically feasible and unless there is a clearly defined need, exclusive market contracts, where flexibility is locked into one market or one product, should be reduced. The terms and conditions in market contracts should not prevent FSPs from offering their flexibility to the markets [57]. This could help FSPs ensure equal access to all markets, either directly or aggregated.

4.1.3.4 Availability of disaggregated data

There could be two approaches to prequalification: unit-based and portfolio-based. Unit-based prequalification is where single or aggregated units are connected to a common connection point and portfolio-based prequalification is where aggregated units are connected to more than one connection point. Currently there is no indication at EU level as to how data from aggregated portfolios with adequate granularity can be made available to TSO/DSO to perform grid-prequalification and grid-assessment. TSOs and DSOs may use extremely conservative margins during grid-prequalification and grid-assessment due to a potential lack of information regarding how each resource within the aggregate contributes to the delivery of the service (i.e. when and how much), which could lead to the imposition of arbitrary restrictions or the inhibition of the bid or service delivery, restricting market access.

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4.1.3.5 Grid constraints representation

The more accurately a market design reflects the physical constraints of the underlying grid, the more market parties' transactions can be accommodated without limitations or the need for corrective actions by the system operator. As an example, with nodal market design, no redispatching is needed by TSOs after the market has cleared, as grid constraints are incorporated in the market clearing algorithm. Locational marginal pricing associated with nodal market design maximizes economic efficiency, considering not only dispatching costs but also the costs of network congestion and losses. As congestion management markets (i.e. redispatching) are mostly used to solve local congestions, having wholesale and balancing markets based on zonal models, i.e. with a less granular degree of grid constraints representation, can increase arbitrage and gaming opportunities, as also highlighted in Section 4.1.1.3.

The sharp increase of new RES assets connected to the grid during the last two decades, often concentrated in new locations (e.g., offshore wind) distant from consumption centers, has not been matched by the speed of reinforcing and extending the transmission and distribution grid. As a result, despite the ongoing network investments, congestions are increasing in many parts of Europe. As such, it can be argued that the current European bidding zone configurations do not sufficiently reflect structural congestions in all the European market areas, leading to suboptimal price signals for generation and demand-side response. The efficiency of the current bidding zones configuration is assessed by ACER every 3 years, considering a technical report on structural congestions prepared by ENTSO-E, as well as a market report evaluating the impact of the current bidding zone configuration on market efficiency, prepared by ACER. A pan-European bidding zone review process is currently ongoing, following the recast of the Electricity Regulation in the Clean Energy Package [58].

When proposing alternative bidding zones, configuration is already a technically complex and highly controversial task. The ultimate decision-making process lies with Member States, where additional political sensitivities and public acceptability play a role. For this reason, having a bidding zone configuration which adequately represents up-to-date grid constraints can be extremely difficult.

4.2 Demo cluster gap analysis

After having obtained the knowledge of various barriers to coordinated and integrated markets presented in section 4.1, a demo cluster gap-analysis exercise was conducted to understand the steps needed to move from markets in isolation (e.g. for a specific System Operator, a specific country, or a specific service) to integrated and scalable markets with seamless coordination between DSOs and TSOs, TSOs and TSOs, DSOs and DSOs, SOs and FSPs (e.g. suppliers/aggregators/consumers/prosumers), within and cross-countries. In Section 4.1 various barriers and harmonization challenges were presented.

Within the joint scope of Task 3.2 and Task 3.4, a dedicated consultation moment in the form of two workshops was organized with all of the country representatives within demo clusters: Northern, Eastern,

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Western and Southern. The objective of the consultation moment was two-fold: first, to present the list of initial theoretical barriers to coordination and integration of markets to demo clusters, obtain immediate feedback on the relevance of each barrier to the country of operation and identify if Task 3.2 has missed any barrier (response captured in the form of survey); secondly, to better understand each country's approach to addressing congestion management and voltage control. The information was captured per-country in order to benchmark markets against each other and capture progress toward integrated and scalable markets.

These consultation moments would eventually allow the demo clusters to adapt their approaches in case this is found to be useful, or vice versa, to challenge the WP3 recommendations with results from the field. In section 3.2.2 we have deep dived into individual countries within the cluster's approach for congestion management and voltage control. Subsequently we have presented the theoretical barriers in section 4.1.

As a part of the first consultation moment with demos, an analysis of the relevance of each of the 21 theoretical barriers for all countries within the demo clusters was conducted. The relevance for each barrier was measured for all countries within the demo cluster on a scale of 0 to 3 with indicators: 'impact' and 'likelihood' being taken into consideration, as shown in the simple matrix in Figure 4-5 below. On the horizontal axis 'likelihood' indicates the frequency as well as the probability of the barrier materializing. On the vertical axis 'impact' indicates the severity of the barrier.

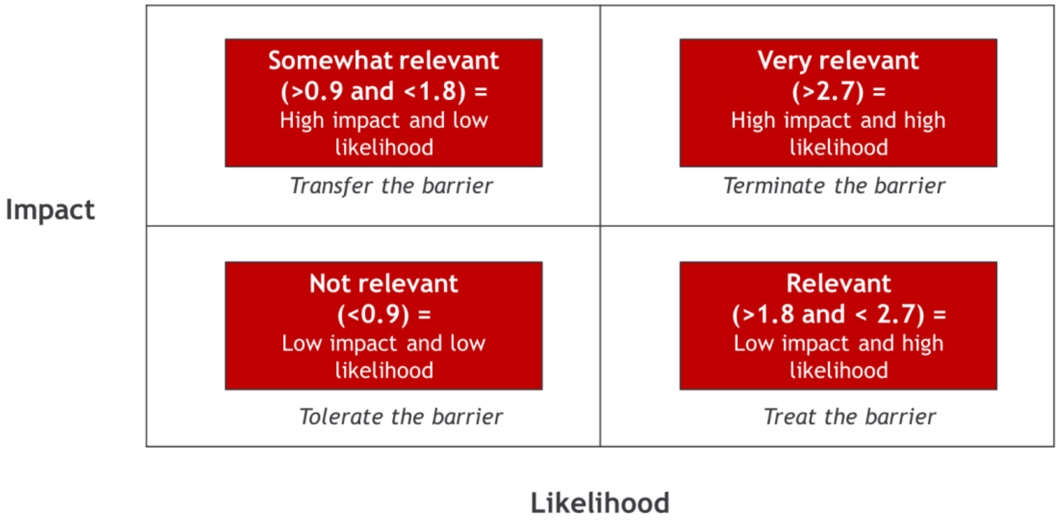

Figure 4-5: Relevance matrix for barriers

The relevance of each barrier was scored on a weighted average basis for each of the cluster regions.

- Not relevant: indicates low impact and low likelihood of the barrier occurring and thus that the barrier can be tolerated.
- Somewhat relevant: indicates high impact and low likelihood of the barrier occurring and thus that the effective management of the barrier could be delegated to another party.

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- Relevant: indicates low impact and high likelihood of the barrier and thus that the responding party is certain to act on treating the barrier.
- Very relevant: indicates high impact and high likelihood of the barrier and thus the barrier is going to have a significant impact on the business or operation and that it should therefore be terminated.

The barriers and harmonization challenges that were identified as relevant or very relevant are shown in Table 4-2 below. The most recurring barriers identified at-least across three or four regions are highlighted in bold.

The second step within the consultation moment was to understand the following:

1. The current approach used in the demo country when addressing congestion management and voltage control.
2. Barriers to the integration of potential congestion management and voltage control markets into the mix of the current energy markets (wholesale and balancing).
3. One of the presented barriers has been identified in the development of the work for OneNet demo and plans to overtake the barriers. For context, better understand whether:
    a. a DSO participates in the congestion management market; and
    b. whether demand facilities and aggregators will participate?
4. Whether demo country plans to test potential congestion management and voltage control via market-based process?

Point 1 above was outlined in Section 3.2.2 above.

The sections below also provide insight into points 2 and 3 above on how various countries within clusters perceive barriers to the integration of potential congestion management and voltage control markets into the mix of the current energy markets (wholesale and balancing) and how they plan on removing any of the barriers based on the development of the work within demonstration efforts.

A ranking is calculated for each barrier in each cluster by multiplying the relative proportion or percentages by their value in sequence and adding those sums together. The summary of the consultation moment, the background analysis (performed per cluster) along with the scoring system can be found in Annex B.

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Table 4-2: Summary of barriers & harmonization challenges identified as relevant or very relevant for Clusters

	Barriers	North-ern	East-ern	West-ern	South-ern
Market Coordination	lack of communication between SOs on formal allocation of products and resources			✓	✓
	lack of coordination between markets on timeframes (especially GOT, GCT and trading resolution of products)	✓	✓	✓	
	lack of coordination between markets on market phases (from prequalification to settlement)				
	implementation of bid forwarding and adequate interfaces		✓	✓	✓
	missing uniform principles on implementation of interoperable flex resource register	✓		✓	✓
Market Architecture & Operation	lack of alignment of prequalification processes			✓	✓
	lack of harmonization for products	✓	✓		✓
	lack of high-level principles of harmonization for market operation (e.g., market clearing type, pricing, procurement frequency ...)	✓	✓		
	lack of harmonized rules for baselining and settlement	✓			
	lack of alignment in technical specifications (e.g., of submeters)	✓			
	different implementations of KORRR data exchange processes and function				
	ensuring appropriate cybersecurity for operators, market participants and consumers	✓		✓	✓
	different sizes of procurement areas depending on the service, grid topology and boundaries managed by the involved SO for market integration				
	uncertainty about the role of the market operator				
Market access and rules for aggregation	existence of exclusive market contracts that lock flexibility into one market	✓			
	lack of (harmonized) interfaces that enable market access for FSP value stacking across timescales and different markets	✓	✓		✓
	lack of harmonization of market optimization methods between markets (centralized, decentralized, distributed)				
	optimization strategy (sequential, simultaneous, or independent clearing of markets)				
	different objectives across markets (maximize welfare, minimize costs, or both)				
	insufficient representation of grid constraints (in the light of more dynamic utilization of the grid)	✓	✓	✓	✓

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4.2.1 Northern cluster

Within the Northern cluster, the following barriers were identified as relevant or highly relevant (the text boxes in Figure 4-6 show the relative ranking based on scoring criteria and the barriers with a value greater than or equal to 1.8 are also indicated below):

- lack of coordination between markets on timeframes (especially GOT, GCT and trading resolution of products);
- missing uniform principles on the implementation of interoperable flex resource register;
- lack of harmonization for products;
- lack of high-level principles of harmonization for market operation (e.g., market clearing type, pricing, procurement frequency);
- lack of harmonized rules for baselining and settlement;
- lack of alignment in technical specifications (e.g., of submeters);
- existence of exclusive market contracts that lock flexibility into one market.;
- lack of (harmonized) interfaces that enable market access for FSP value stacking across timescales and different markets.;
- insufficient representation of grid constraints (in the light of more dynamic utilization of the grid);
- ensuring appropriate cybersecurity for operators, market participants and consumers.

In general, countries within the Northern cluster consider facilitating easier market access for FSPs as one of the biggest challenges. The market access could be a single access point to the market for FSPs (e.g. via market operator, flexibility register). The countries within the Northern cluster also consider avoiding large number of products and overlapping of different products (for e.g., intraday, and near-real-time products should be sequential). By defining common products for different needs or services, it would be possible to have higher liquidity on the market. Finally, from a cybersecurity point of view, it is especially important to have secure data exchanges along with tools for data privacy and consent management.

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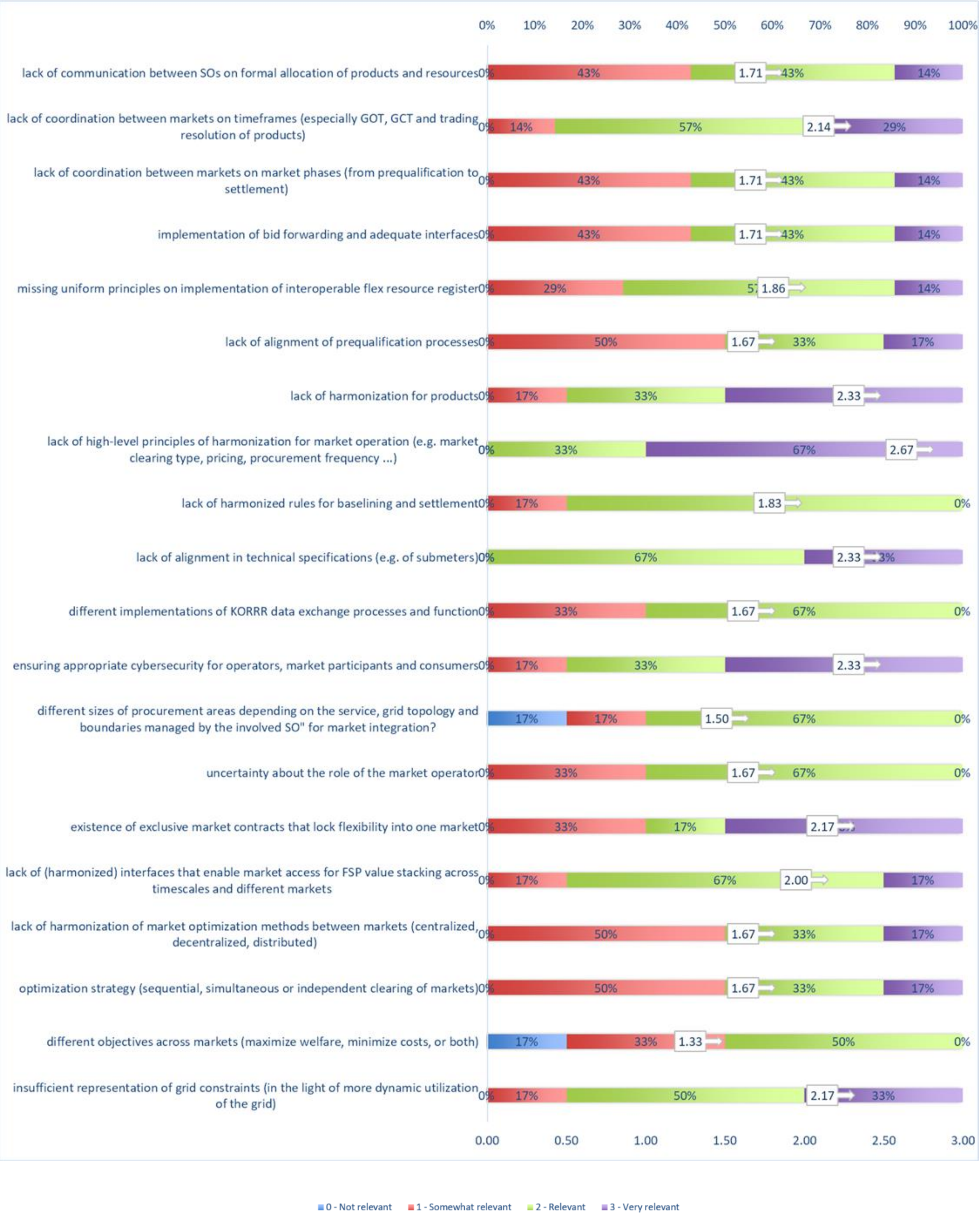

Figure 4-6: Northern Cluster Barriers

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4.2.2 Eastern cluster

Within the Eastern cluster, the following barriers were identified as relevant or highly relevant (the text boxes in Figure 4-7 show the relative ranking based on scoring criteria and the barriers with a value greater than or equal to 1.8 are also indicated below):'

- lack of coordination between markets on timeframes (especially GOT, GCT and trading resolution of products);
- implementation of bid forwarding and adequate interfaces;
- lack of harmonization for products;
- lack of high-level principles of harmonization for market operation (e.g. market clearing type, pricing, procurement frequency ...);
- lack of (harmonized) interfaces that enable market access for FSP value stacking across timescales and different markets;
- insufficient representation of grid constraints (in the light of more dynamic utilization of the grid).

In Slovenia, currently there is no integration platform between TSOs and DSOs. In addition to this, DSOs are at different stages in the implementation of advanced distribution management system (ADMS) and thus there is no common level of understanding and investment/development priorities between DSOs. Furthermore, in Slovenia, there are technical limitations on the DSO side regarding fast network analysis in real-time horizon thus limited the possibilities of clients to provide of balancing services and CM/VC.

Based on the input from Eastern cluster demonstrators in the workshop, there is no common stance on the CM and VC market potential between market participants (TSO, DSO and FSPs). Also, there is no clear decision on the market design, its scope, and participants‘ roles.

In Poland communication between TSO and DSO is still developing due to nature of the current central dispatch model. One of the biggest barriers identified in Poland is that there is low awareness of customers and other system users about the possibility of providing services to DSOs and TSOs (especially balancing services). The current balancing market is addressed primarily to centrally-controlled large generating units. In addition to this, there are no national regulations for inclusion of cost related to purchase of flexibility services by DSOs in the tariff. Similarly, In Slovenia there is no regulatory framework which includes cost recovery mechanism for the procurement of flexibility services.

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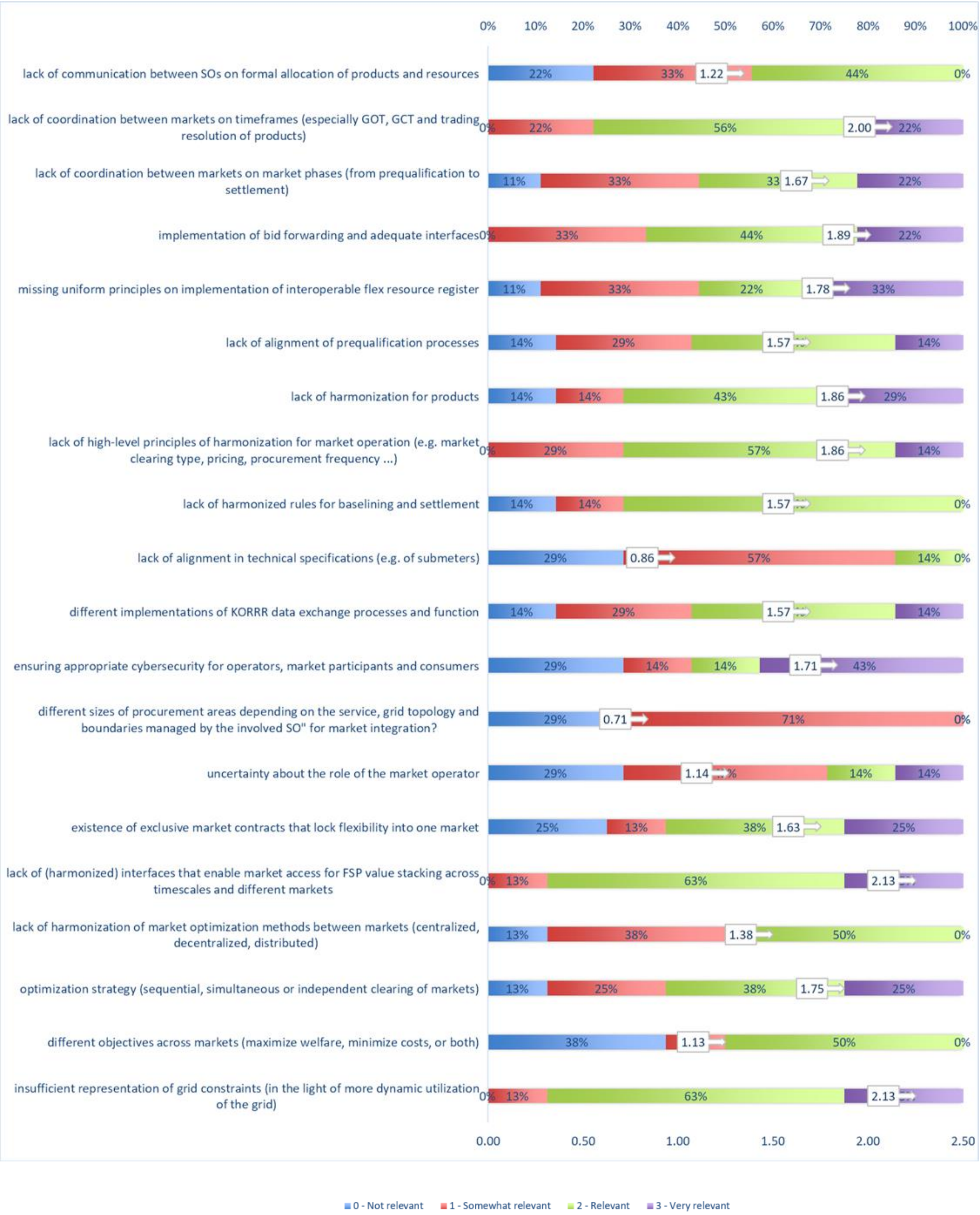

Figure 4-7: Eastern Cluster Barriers

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4.2.3 Western cluster

Within the Western cluster, the following barriers were identified as relevant or highly relevant (the text boxes in Figure 4-8 shows the relative ranking and the barriers with a value greater than or equal to 1.8 are also indicated below):

- lack of communication between SOs on formal allocation of products and resources;
- lack of coordination between markets on timeframes (especially GOT, GCT and trading resolution of products);
- lack of coordination between markets on market phases (from prequalification to settlement);
- missing uniform principles on implementation of interoperable flex resource register;
- lack of alignment of prequalification processes;
- ensuring appropriate cybersecurity for operators, market participants and consumers;
- insufficient representation of grid constraints (in the light of more dynamic utilization of the grid).

In Spain, the barrier identified is related to real-time market coordination whereas in France the challenge is TSO-DSO coordination and data sharing, especially for the product prequalification, dynamic qualification, and the settlement phase. Additionally, data confidentiality is one of the barriers identified in France. In Portugal and Spain, the biggest barrier at DSO level is that there is no regulatory framework to support the integration of congestion management and voltage control markets into the sequence of the current energy markets. Since there is no regulatory framework and no coordination between DSO and TSO, the Portuguese demo is attempting to mitigate the barrier through a simulation-based approach and by focusing on the exchange of information between the DSO and the TSO.

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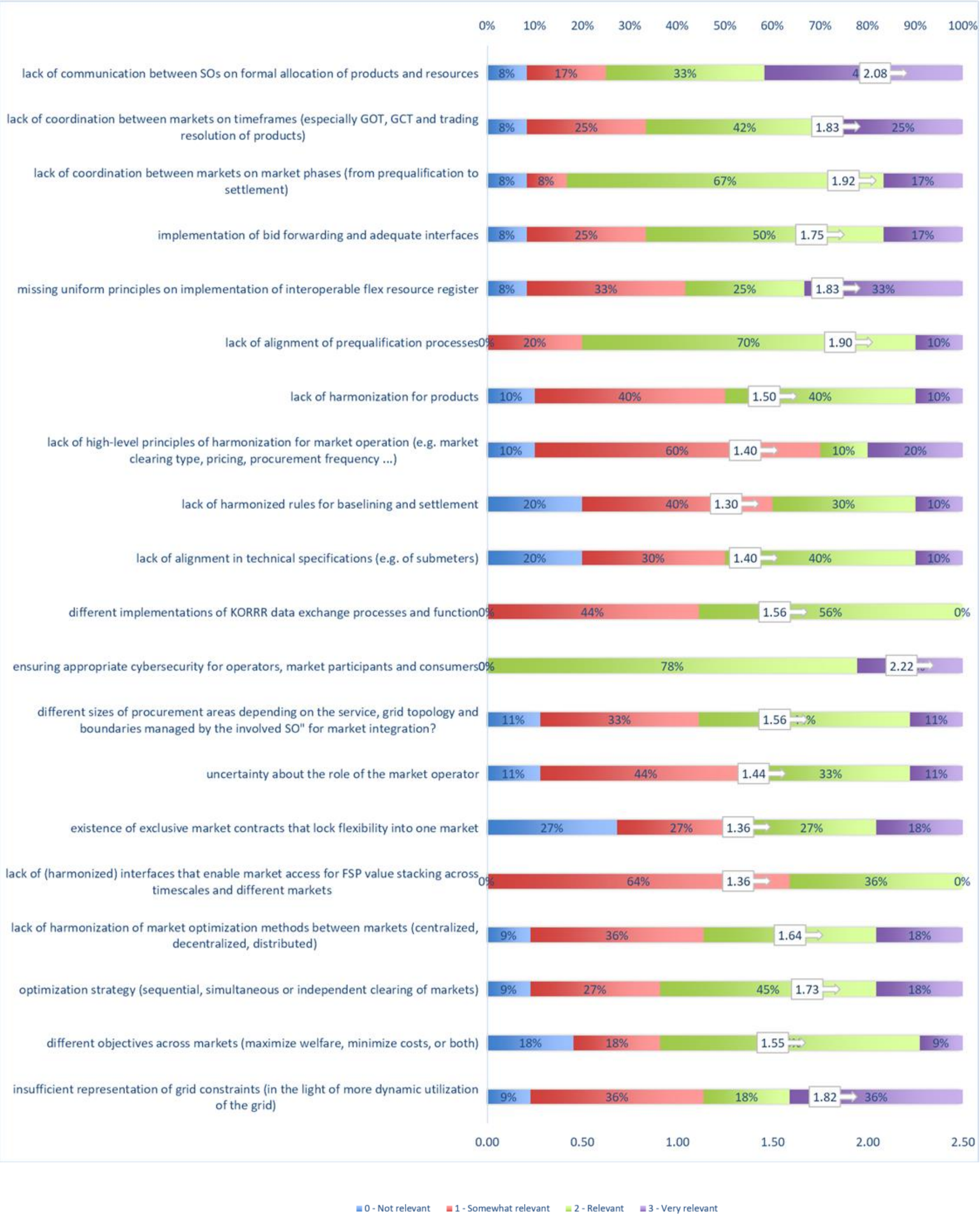

Figure 4-8: Western Cluster Barriers

4.2.4 Southern cluster

Within the Southern cluster following barriers were identified as relevant or highly relevant (the text boxes in Figure 4-9 show the relative ranking and the barriers with a value greater than or equal to 1.8 are also indicated below):

- lack of communication between SOs on the formal allocation of products and resources;
- implementation of bid forwarding and adequate interfaces;
- missing uniform principles on the implementation of interoperable flex resource register;
- lack of alignment of prequalification processes;
- lack of harmonization for products;
- ensuring appropriate cybersecurity for operators, market participants and consumers;
- lack of (harmonized) interfaces that enable market access for FSP value stacking across timescales and different markets;
- insufficient representation of grid constraints (in the light of more dynamic utilization of the grid).

In Cyprus, currently there is no fully functioning electricity market on the island (the TSO market was expected to launch by end of 2022 while the local DSO market model is not defined yet). Congestion management is envisioned to be considered within the day-ahead planning as a constraint. Voltage control is not a market product but an obligation on the participants in the market, either conventional or RES (according to grid regulations). There is limited coordination between TSOs and DSOs. However, there are plans to implement the coordination approach prescribed in the ASM report in 2022 (ASMReport). In addition, there is limited network observability at the distribution level.

Most of the obstacles in the Greek case can be attributed to the lack of the appropriate infrastructure, either physical or digital. There is a lack of communication between SOs on the formal allocation of products and resources (TSO congestion management is currently integrated into the market and further integration will be implemented in 2022 to include renewable sources' production and demand side response). Greece also plans to implement the coordination approach prescribed in the ASM report in 2022. In Greece the flexibility resources register is not yet adopted.

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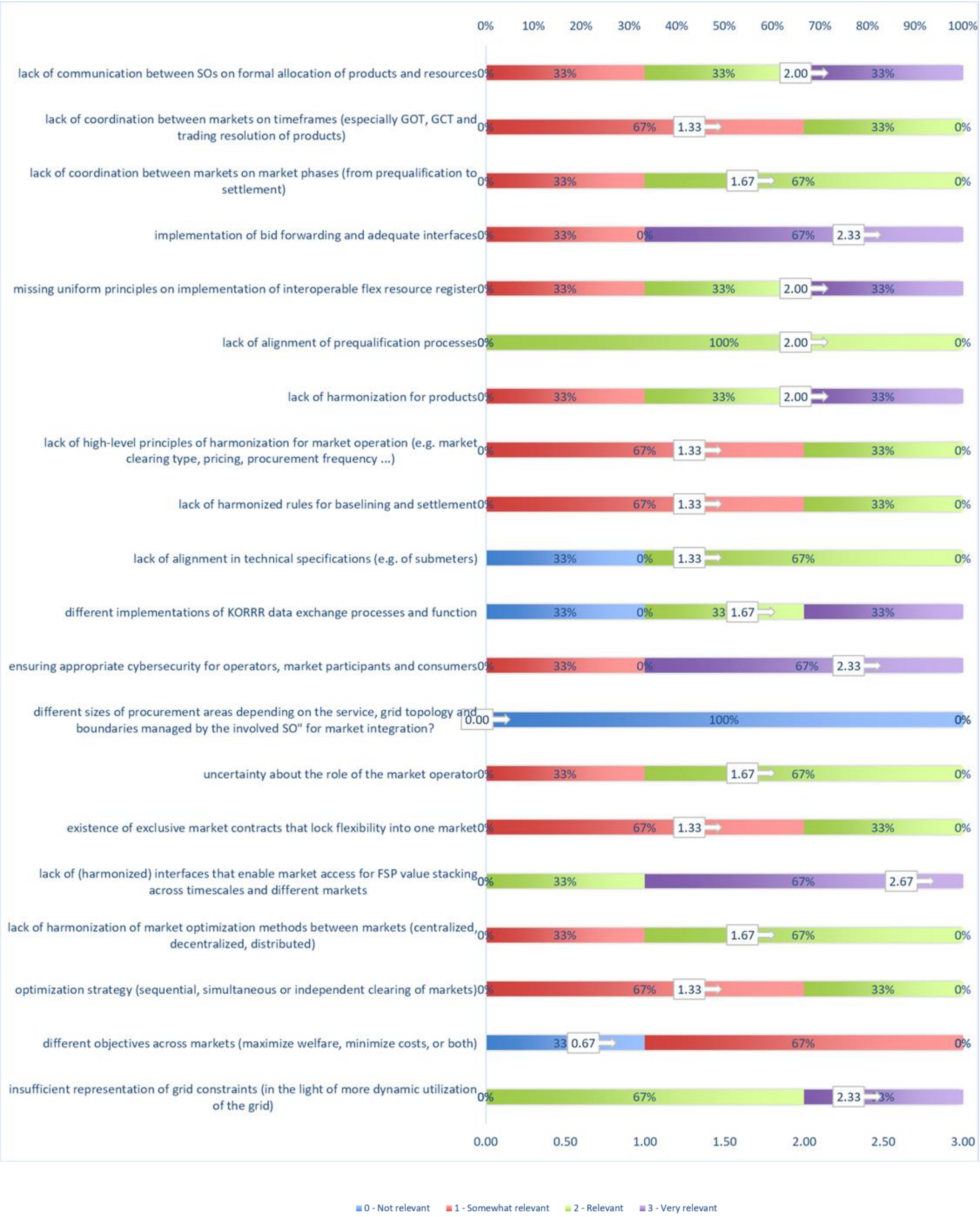

Figure 4-9: Southern Cluster Barriers

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4.3 Consolidated overview of barriers to integrated and coordinated markets

As a next step in our methodology, we brought together the barriers identified in Sections 4.1 and 4.2, supplemented with barriers retrieved from literature or derived from internal and external discussions.

All these barriers were then linked to the objectives of coordinated and integrated markets, defined in Section 3.3.2 and restructured into the overview that is presented in Figure 4-10, which provides, for each objective, an overview of the barriers.

	Objectives		Barriers
Coordination objectives	**Maximization of value stacking**	**B1**	Insufficient coordination of flexibility markets for system services with energy markets with regard to timing.
		B2	Insufficient coordination of different system services over different timeframes, valid for all market phases, i.e., prequalification, baselining, procurement, activation, monitoring and settlement.
		B3	Lack of harmonization of flexibility products for system services for both TSO and DSO
		B4	Exclusivity clauses and non-harmonised contracts
	Cost-efficient acquisition of flexibility	**B5**	Coordination of explicit procurement of flexibility (flexibility markets) with implicit procurement of flexibility (tariffs, connection agreements,…)
		B6	No specific incentives in the regulatory mechanism (remuneration) that support a common approach between SOs for flexibility procurement
	Operationally efficient market procurement process for flexibility	**B7**	Limited cross-border coordination/integration
		B8	Limited coordination for procurement of flexibility by DSO and TSO
		B9	Lack of alignment in supporting processes such as prequalification, monitoring and settlement processes including baseline approach.
		B10	Lack of established methodology for network representation for the distribution grid
	Ability to exchange, host, and process data in a timely and secure manner	**B11**	ICT challenges: Large uncoordinated collection of data, timely exchange of (confidential) network information, etc.
Integration objectives	**Efficient market access for all FSPs, for all voltage levels, for all technologies**	**B12**	No appropriate baseline methodology and process established for new flexibility markets and new types of flexibility providers (e.g. low voltage flexibility)
		B13	No uniform access and registration process/platform for assets willing to participate to flexibility markets.
	Ensuring an equal level playing field for all market actors without unwanted side effects such as market power or risk of gaming	**B14**	Risk of gaming due to exertion of market power and/or shortcomings in the market setting
	Maximizing the benefits of sector integration	**B15**	Lack of coordination of markets of different carriers
		B16	Quantification of the benefits of sector integration is missing
	Adequate incentives for participation through availability of relevant information (e.g., anticipated flex needs, etc.)	**B17**	Unavailability of adequate information allowing FSPs to anticipate the value of their participation and hence not being able to quantify their business case

Figure 4-10: Summarized overview of the objectives and identified barriers

Figure 4-10 above consolidates the objectives and barriers together and includes the following:

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1. The coordination/integration objective
2. For each objective, a list of barriers
3. For each barrier, an explanation that clarifies what exactly is meant by that barrier.

The overview of the barriers as well as the explanation for each barrier given in Table 4-3 below was shared with the demos and Task 3.2 partners, together with a series of questions on how to remove these barriers, in a survey. The template for the questionnaire for the demos can be found in Annex C while the template for the Task 3.2 partners can be found in Annex D. The difference between the two surveys is that in the demo questionnaire, we are looking for specific, practical solutions to remove the barriers while in the partner questionnaire, we are expecting more theoretical answers.

The following section explains the results of the survey.

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Table 4-3: *Overview and explanation of barriers to coordinated and integrated markets*

Objective	Barrier	Description
Maximization of value stacking	B1. Insufficient coordination of flexibility markets for system services with energy markets with regard to timing.	Existing flexibility markets such as balancing and energy (wholesale) markets are organized as separate sequential or sometimes even overlapping markets. Aside from these more mature markets, local flexibility markets (e.g. for congestion management) are being set up and integrated into this market sequence. Some of these markets are energy only markets, while others entail capacity reservation. Even if FSPs are allowed to participate in these different markets, this increased complexity and lack of coordination between the markets limits the opportunities for FSPs to participate in multiple markets. Moreover, a capacity that has been committed in one market (e.g., reserve capacity procurement) cannot be offered in the subsequent market (e.g., day-ahead market (DAM)). FSPs hence have to decide in which markets to submit their bids and, as a consequence, cannot maximize value stacking due to inefficient allocation of resources [59]. Moreover, some new flexibility markets, e.g., for congestion management, are cleared months ahead locking in vast amounts of flexibility. As it is difficult to predict, flexibility needs longer term ahead, this might lead to situations where too much flexibility is reserved at too high costs. Overall, this barrier thus decreases opportunities for FSPs to stack value across different, sequential markets, which can decrease their return on investment. This barrier is also closely linked to barrier B8, as better coordination of the timing of different markets has the potential to increase the overall efficiency of the different markets through more efficient allocation of flexibility and, as a result, will lower the overall system costs
	B2. Insufficient coordination of different system services over different timeframes, valid for all market phases, i.e., prequalification, baselining, procurement, activation, monitoring and settlement.	This barrier looks at the timing aspects of the different market phases and supporting phases, which are currently not aligned. For instance, if the prequalification process of one market would be later compared to other markets, an FSP would have no certainty if they would be eligible to participate in the latter market, which may be more interesting when deciding to qualify for the former. Also, a lack of coordination during the procurement process could result in conflicting cross-activations or assets blocked (e.g. by an availability

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		market) that cannot participate in other markets. Insufficient coordination of monitoring could affect network operation or the quantification of the needs and uncoordinated settlement may lead to increased costs for the management of cashflows between the market players. Overall, it can be concluded that, if the timing of these different processes is not well aligned between markets for different services, the costs for FSPs, but also overall system costs, are higher as compared to coordinated procedures and processes.
	B3. Lack of harmonization of flexibility products for system services for both TSO and DSO	Product harmonization for balancing products is already well under way, even at the European level (e.g., PICASSO, MARI, TERRE) (see also barrier B7). At the same time, both TSOs and DSOs are defining products for congestion management and other non-frequency ancillary services. Certainly, more locational products for the DSO are very often defined based on specific local needs and contexts and are therefore very often not aligned with established balancing products, leading to a proliferation of different product definitions. This increased complexity due to diverging products limits the participation of FSPs in multiple markets. Moreover, when product specifications for locational products and system-level products are not aligned, the opportunities of merging these flexibility markets into a common market with a single product providing multiple services is hindered, thereby also decreasing the value stacking potential of FSPs. This barrier is thus closely linked to barrier B8 which discusses the lack of coordination between TSOs and DSOs for flexibility procurement (see below).
	B4. Exclusivity clauses and non-harmonized contracts	Non-harmonized contracts and exclusivity clauses in the terms and conditions of contracts between FSPs and market operators for different markets limit the participation of FSPs to multiple markets and revenue streams and, hence, reduce the liquidity in the market. Even if products in different markets would be harmonized (see barrier B3), if the contracts in these markets are not harmonized or if one or more of the contracts contains exclusivity clauses, this can still pose a barrier for value stacking. Moreover, the contracts with suppliers may be restrictive for end- consumers wanting to participate in the flexibility market and/or enter into a contract with an independent aggregator.
Cost-efficient acquisition of flexibility	B5. Coordination of explicit procurement of flexibility (flexibility markets) with implicit	Conflicts on remuneration and accounting of energy flows may arise when implicit and explicit flexibility mechanisms are combined but not well coordinated.

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It is important to note that there are 2 points of view for cost-efficient flex acquisition: i) point of view of the individual SO, and ii) from the system perspective	flexibility mechanisms (tariffs, connection agreements, …)	E.g. a customer has two different contracts, one with its supplier for implicit DR and one with an independent aggregator providing explicit DR. This means that the effect on the energy bill of the customer should be considered in the remuneration for explicit flexibility. Moreover, distribution grid tariffs are shifting towards capacity-based tariff designs and/or time-varying tariffs which better reflect grid costs, which adds to the complexity. In this case grid users can thus be exposed to conflicting signals and, when assessing the business case for explicit flexibility provision, would have to weigh the benefits of explicit flexibility provision against potential increased costs due to flex activation. It is thus important to take into account the conflicting effect of implicit and explicit flexibility mechanisms when designing flexibility markets, developing commercial market signals as well as revising transmission and distribution grid tariffs to avoid overall increased costs for flexibility procurement due to inefficiencies in the design of these mechanisms. While important and relevant, this barrier falls outside of the scope of the survey, and hence, barrier solutions, as the demos, which serve as the main input for the solutions, only focus on explicit procurement of flexibility.
	B6. No specific incentives in the regulatory mechanism (remuneration) that support a common approach between SOs for flexibility procurement.	The way system operators are financed, the so-called remuneration mechanism, has an important impact on the use of flexibility. To allow for a correct tradeoff between the use of flexibility versus investments in the grid, combined incentives are needed considering both capital and operational expenditures. Today, we see a shift towards remuneration mechanisms for TSOs and DSOs which do consider this combined effect. However, approaches still diverge and do not account for possible synergies between TSOs and DSOs. If the remuneration mechanism to decide on the acquisition of flexibility is divergent between DSOs and TSOs, there is no financial incentive for SOs to select a solution that results in the lowest total system cost even if this may result in a higher cost for an individual system operator.
Operationally efficient market procurement process for flexibility	B7. Limited cross-border coordination/integration	Despite the ongoing European harmonization initiatives for balancing markets and platforms (PICASSO, MARI, TERRE), some barriers with regard to cross-border coordination/integration still remain. For instance, current European rules are not ideal for joint optimization between balancing and local products (congestion management, voltage control). Balancing optimization takes place on the European platforms (e.g., MARI) and these platforms are only dealing with non-locational

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		issues (balancing) and do not consider locational issues such as local congestion. The other way around, if SOs want to optimize locally for congestion management, it is unclear if they can address, at the same time, also balancing needs for the same country/region, i.e., is it allowed of the same set of congestion bids also corrects the initial imbalance and/or includes the bids which counterbalance other bids that would otherwise cause additional imbalance. Moreover, even if SOs would be allowed to do that, they have no view, at this stage in time, on which bids will be activated for the needs of other European countries. Other reasons for this barrier are different market designs which can pose barriers to market entrance for aggregators who want to act across borders.
	B8. Limited coordination for procurement of flexibility by DSO and TSO.	Different flexibility markets are at different maturity levels, e.g. frequency ancillary services markets are already very mature, while markets for congestion and voltage control both for the DSO and the TSO are still under development in most countries. The importance of coordination between TSOs and DSOs to ensure the security of supply is widely accepted. There is however no shared view yet on how such coordination should be organized. Several coordination models and resulting rules for flexibility allocation therefore exist, e.g., the SmartNet project [31], the CoordiNet project [32], which entail different levels of coordination between the TSO and DSOs. The CoordiNet project found that a joint / common market model can provide higher procurement efficiency from an optimization stand point, as the common market pools all resources and purchases the bids that can most optimally meet all the participating SOs' needs [33]. Hence, if the rules for priority/exclusivity diverge from the optimal resource allocation, the cost efficiency will also be lower. However, it is also noted that, in practice, separate markets might be introduced with diverging products, capturing the possibly diverging needs of DSOs and the TSO and the technical and financial capabilities of FSPs. If every DSO, however, organizes its own market to cover its own needs, this could lead to market fragmentation and higher costs as possible synergies between markets are not realized. On the other hand, there seem to be quite some hurdles to realizing more joint approaches, which need further attention. In practice, we see that very different approaches are being demonstrated and implemented across Europe, very often with limited coordination. There does not

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		seem to be one preferred coordination scheme that suits all needs and contexts, and best practices or general guidelines are still lacking.
	B9. Lack of alignment in supporting processes such as prequalification, monitoring and settlement processes including baseline approach.	Existing (and upcoming) flexibility markets have different procedures for the different market phases. Overall, there is a lack of aligned and uniform processes for different services in a certain country and on EU level, leading to inefficiencies. This barrier addresses all aspects of the different market phases which are not related to timing, i.e., the rules, procedures, etc. as timing aspects are already covered in barrier B2 and also excludes the procurement phase as this was covered in barrier B8. Different prequalification methods exist across Europe, but also on the country level for different services. Currently, separate prequalification procedures are very often organised for existing services (e.g. balancing services for the TSO). In addition, DSOs are setting up their own processes. This means that an FSP wanting to offer multiple services (e.g. balancing and congestion managements services) and hence stack value across the different markets would need to pass through two different prequalification procedures. This implies a higher effort and cost for the FSP as they would need to understand and participate in two different procedures. For prequalification, the DRFG [4] also specifically mentions a lack of alignment in grid prequalification: (i) lack of harmonised assessment criteria between SOs, (ii) unclear concepts of conditional/long-term and dynamic/short-term prequalification, and (iii) unclarity in roles of different SOs involved in the process (connecting SO, intermediate SO, etc.). If similar procedures for different services were put in place, whenever and to the extent that this is possible, this would increase efficiency for potential market participants willing to participate in different services. Similar reasoning can be followed for monitoring and settlement approaches. It should however be noted that the settlement processes require the collection of measurements (i.e., baselines, actual measurements and original activation request information) with the necessary granularity and frequency depending on the service under consideration. Further insights are therefore needed on the extent to which these processes can be aligned, but also on the potential impact diverging approaches could have on the settlement of delivered flexibility for different services. The baseline together with the actual measurement forms the basis for the amount of flexibility to be settled. When it comes to baselining, different services

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		may have different baselining requirements and the need to observe different parameters, but synergies between different markets might still be sought for. This is covered in more detail in barrier B12.
	B10. Lack of established methodology for network representation for the distribution grid	Flexibility activations need to stay within the limits of the grid and the impact of flexibility on the network should be properly assessed. More and more flexibility is being sourced from distribution grids, by the DSO to support their needs and by the TSO to support the overlaying grids. To be able to correctly estimate the impact of activation of flexibility on the distribution grid a sound methodology for network representation is needed. This would serve two goals: a) estimation of the impact of flexibility activation by other actors (e.g. TSO) on the distribution grid (during grid prequalification or during the market clearing) and b) correct estimation of the contribution of flexibility on the considered DSO need. The more accurately a market design reflects the physical constraints of the underlying grid, the more market parties' transactions can be accommodated without too extensive limitations or the need for corrective actions by the DSO. Inadequate network representation in the market on the other hand can lead to network violations or inefficient procurement of flexibility (e.g. too much flexibility). An established methodology is however currently lacking.
Ability to exchange, host, and process data in a timely and secure manner	B11. ICT challenges: Large uncoordinated collection of data, timely exchange of (confidential) network information, etc.	The establishment of new flexibility markets and the incorporation of new types of flexible resources in these markets brings along a large amount of data that needs to be exchanged and coordinated. This relates to data needed to estimate flexibility needs (e.g. forecasts, grid needs), but also data on flexibility delivered (e.g. baselines, measurement data). This brings along new challenges on how to manage, host and protect this data. While important and relevant, solutions to this barrier are being addressed in OneNet's WP4, 5 and 6. Therefore, we will not focus on this barrier in the barrier analysis and solution description.
Efficient market access for all FSPs, for all voltage levels, for all technologies	B12. No appropriate baseline methodology and process established for new flexibility markets and new types of flexibility providers (e.g. low voltage flexibility)	Several different baseline methodologies are used in the context of existing and emerging flexibility markets. Existing services typically have well established methodologies that are differentiated depending on the service and products, while emerging markets (e.g. local flexibility markets for congestion management and voltage control) are still investigating appropriate methodologies. A commonly agreed methodology for baselining these new markets is currently lacking, leading to different approaches across Europe.

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		Also, new types of flexible resources might require different approaches. When specifically looking at low voltage (LV) consumers, it should be emphasized that quantifying the amount of flexibility (typically expressed as energy) that has been delivered by LV consumers is not straightforward, due to the stochasticity of residential consumption, the absence of appropriate data and the lack of an appropriate methodology for baselining of LV consumers [60]. While it is important to note that we should strive for a harmonized procedure for all voltage levels, we specifically focus on LV in this barrier as LV currently represents the biggest challenge with regard to baseline methodology, and hence, market access for flexibility providers. Moreover, new types of flexible resources might require different approaches. Best practices on how to create a baseline specifically for LV flexibility are currently not available. The difficulty of establishing baselines for LV is also mentioned in the Consumer-Centric market design (CCMD) paper as proposed by Elia [61].
	B13. No uniform access and registration process/platform for assets willing to participate to flexibility markets.	The lack of uniform registration processes or platforms makes it more difficult for FSPs to gain access to different markets as they have to understand and use different processes for the different markets, and it leads to duplication of information and requests. In addition, these access and registration processes (as part of the prequalification process) very often still lack automation and still require manual interventions (e.g. by email) or requests per flexible resource, which constitutes a large administrative burden. With the introduction of new flexibility markets and the advent of larger amounts and new types of smaller flexible resources entering the market these processes need to be thoroughly reviewed.
Ensuring an equal level playing field for all market actors without unwanted side effects such as market power or risk of gaming	B14. Risk of gaming due to exertion of market power and/or shortcomings in the market setting	Market power is the ability of market participants to influence market prices through their decisions, offerings, and positions in the market. The exertion of this market power represents a direct gaming risk by the agents. The existence of market power can directly stem from different factors such as the liquidity aspects of the market, the nature of flexibility needs, and the sizes and distributions of market participants. For example, a highly localized market may not have a large set of providers for the procured service (e.g., local congestion management or voltage control), which – in the extreme sense – may indicate that all providers available would be needed to provide the service. In such a setting, since each provider is necessary, each has market power and can influence the market outcome (e.g., through price setting /

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		manipulation). Along similar lines, entry requirements can have a direct impact on the ability to exert market power due to their direct effect on driving down liquidity. The pricing method itself, can also lead to different strategic behaviors, through which each market agent can aim at maximizing their profits through an artificial setting of bid prices that do not always reflect their corresponding marginal costs. Gaming potential can also be driven by the nature of the market structure. For example, in sequential markets, a market participant can take up decisions in one market layer to influence the needs (and operation) in the following market, in order to capitalize on this process (as in the infamous inc-dec game, or in settings where capacity is withdrawn to lead to artificial acute system needs). These mechanisms can be more pronounced when market actors can foresee with an increased level of accuracy the functionality and expected prices and (flexibility) needs in each of the markets. The settlement and baselining methodology can also play a direct role in driving potential gaming potential, as certain baseline calculation methodologies can incentivize the reporting of inaccurate baselines, which miscalculates the level of the provided service, and hence, the remuneration of the flexibility providers and the total cost to the system.
Maximizing the benefits of sector integration	B15. Lack of coordination of markets of different carriers	Markets for different carriers (e.g. gas, heat) are typically evolving towards more short-term trading (e.g. day-ahead, intraday), but are typically organized separately, with little consideration of potential synergies (e.g. no alignment of market timings). This complicates the market participation of flexible resources that link several carriers, so called conversion technologies [62]. For instance, the physical coupling of energy carriers through such technologies is not reflected in the timing of markets for different carriers. In this context, the revenue of a conversion technology (e.g. gas turbine) depends on the forecast accuracy of market prices in the input (gas) and output (electricity) carrier. Without proper coordination between markets of different carriers such technologies are thus exposed to substantial risks due to imperfect forecasts which can result in a loss of profit. If this physical coupling between carriers is not properly accounted in the market design of the different carriers, the market outcomes are not guaranteed to be technically feasible and/or economically attractive for market participants with conversion technologies.

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		Although important and relevant, this barrier is not taken up in the survey as OneNet focuses on system services for power systems and sector integration is not addressed by the demos. Solutions to this barrier will hence not be discussed in this deliverable.
	B16. Quantification of the benefits of sector integration is missing	There is a common agreement that sector integration is important to achieve a low carbon energy system as it allows optimization of the energy system as a whole as opposed to each sector individually. Sector coupling on the end-user side (e.g. electrification of the heating and transport sector) is seen as one of the important measures to move to a carbon-free energy system with the needed flexibility. A thorough quantification of the benefits of sector integration is, however, lacking. This creates uncertainty for consumers willing to invest in new types of technologies which can realize sector coupling (e.g. EVs, heat pumps). These technologies typically have a higher investment cost compared to alternative technologies and – at the same time - an uncertain future revenue, certainly with respect to the expected income from exploitation of flexibility in support of the electricity grid. Although important and relevant, this barrier is not taken up in the survey as OneNet focuses on system services for power systems and sector integration is not addressed by the demos. Solutions to this barrier will hence not be discussed in this deliverable.
Adequate incentives for participation through availability of relevant information (e.g. anticipated flex needs, etc.)	B17. Unavailability of adequate information allowing FSPs to anticipate the value of their participation and hence not being able to quantify their business case	New potential FSPs typically have a low level of awareness and understanding of grid related issues and the potential for flexibility delivery since flexibility provision is not their core business. They may come even from non-energy domains. This barrier therefore relates to the lack of knowledge of these new flexibility providers on the flexibility markets and their economic advantages and the deficiency of communication and information from the market. This can relate to a lack of information on market functioning and processes, volume of expected flexibility needs, anticipated activation times, frequency of activation and expected prices, but also to more transparency on the market outcome. This type of information would help FSPs to estimate their expected revenue and assess their return on investments (e.g. for needed investments in control and measurement equipment) and make an informed decisions on their participation in the market.

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5 Solutions to attain integrated and coordinated markets

In this chapter, we discuss the solutions to remove the barriers to integrated and coordinated markets. We start from the barrier overview provided in Figure 4-10. We first present the solutions applied by the demos, followed by an overview of TSO-DSO coordination schemes proposed in other projects. To conclude this chapter, the demo solutions from the first step are mapped to the OneNet solutions.

5.1 Responses from the questionnaires

In this section, we present an overview of the responses to the demo with regard to the barriers. First, a general overview is provided, followed by a detailed overview of the answers at the demo level.

5.1.1 General overview of the demos' responses

For the reader's convenience, an overview of the different demo's, the geographical cluster to which they belong, and the demo coordination type is given below in Table 5-1. More information on the demo coordination can be found in [63].

Table 5-1: Demo overview on coordination type

Demo	Cluster	Coordination type
Northern	Northern	market-based TSO-DSO coordination
Czech Republic	Eastern	market-based DSO coordination
Hungary	Eastern	market-based DSO coordination
Poland	Eastern	market-based TSO-DSO coordination
Slovenia	Eastern	market-based DSO coordination
Cyprus	Southern	market-based TSO-DSO coordination
Greece	Southern	technical-based TSO-DSO coordination
France	Western	technical-based TSO-DSO coordination
Portugal	Western	technical-based TSO-DSO coordination
Spain	Western	market-based DSO coordination

For each of the barriers, we asked the demos if the specific barrier was relevant for their demo and if it was addressed[17]. If a specific demo addressed the barrier, we asked them how. Figure 5-1 provides an overview of the number of times a specific barrier was addressed, and by which specific demo.

[17] Please note, that as mentioned in Section 4.3, B11 and B16-B18 are not taken into account.

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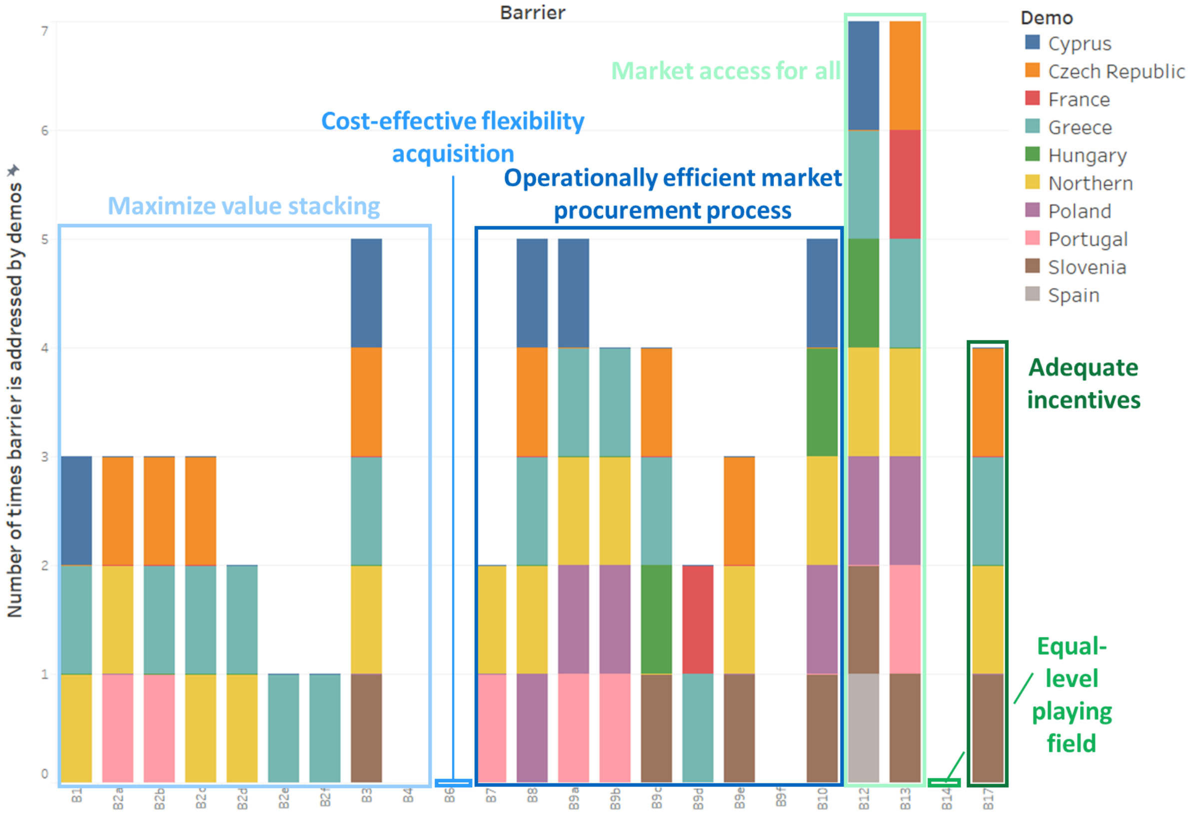

Figure 5-1: Overview of barriers addressed by the demos, per demo[18]

The specific use cases of the demos and the coordination type (technical versus market-based, TSO-DSO versus DSO) determine to which extent the demos address the barriers.

The following sections describe in more detail how the different demos address the barriers.

5.1.2 Northern cluster

The Northern cluster have developed a regional demo approach where unified solutions are developed for the entire demo cluster, coupled with specific instances of demonstration of these unified solutions on the different country levels (Finland, Estonia, Latvia, and Lithuania). The type of coordination used is market-based TSO-DSO coordination. The objective of this demo is to demonstrate harmonised products, which can be implemented in more than one country of the region and for more than one need/service. The demo implements a market setup that selects the best possible set of bids according to the total cost and technical constraints (i.e. grid capability). The demo employs a flexibility register and coordination platform to facilitate the coordination.

For more information on products, services and platforms, please refer to [63].

The overview of the barriers addressed by the Northern demo and their solutions are provided in Table 5-2.

[18] Please note, that as mentioned in Section 4.3, B11 and B16-B18 are not taken into account.

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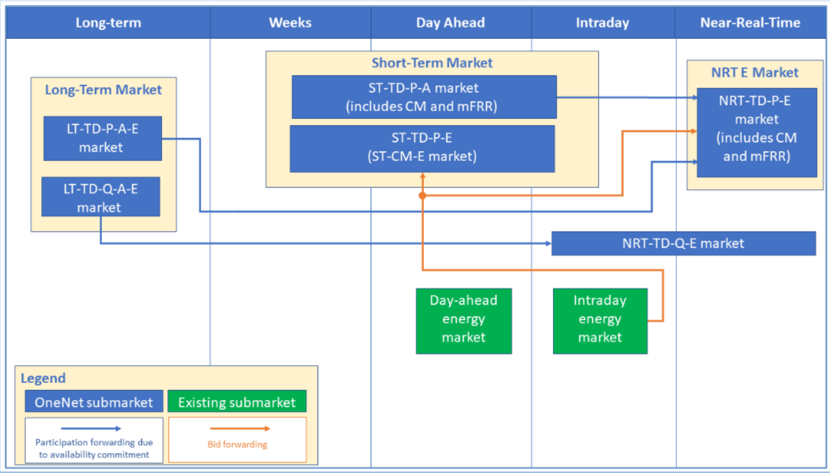
Table 5-2: Overview of addressed barriers and solutions for the Northern demo

No	Barrier	Solution
B1	Insufficient coordination of flexibility markets for system services with energy markets with regards to timing.	The demo solves this barrier by coordinating gate closure times for the different markets. More specifically, the GCT for the short-term active energy (ST-P-E) product is the same as for intraday market and near-real-time active energy (NRT-P-E) product gate closure (25 minutes before delivery period) will come after intraday market (and ST-P-E) gate closure (see figure below, taken from [63]). The reason this sequence is chosen is that, for the NRT-P-E product to be optimised in a reliable way, one needs to know which bids were selected for the ST-P-E product and what the impact of these bids is for flows in the grid. 
B2a	Insufficient coordination of different system services over different timeframes for pre-qualification	This barrier is solved by employing a single point for prequalification. In the case of the Northern demo, this is done using a Flexibility Register (FR). See B9a for more information on the process.
B2c	Insufficient coordination of different system services over different timeframes for procurement	Coordination for procurement takes places through the Northern demo's TSO-DSO Coordination Platform (TDCP). This is the central point for bid optimisation for all products in the demo. To avoid discrepancies, (energy) products (ST-P-E and NRT-P-E) should be sequential in terms of gate closure (see B1). For instance, before the NRT-P-E product can be optimised in a reliable way, it is needed to know which bids were selected for ST-P-E product and what is their impact to flows in the grid. However, co-optimisation coordination with European platforms like MARI will be a future challenge.
B2d	Insufficient coordination of different system services over different timeframes for activation	The solution to this barrier also lies in the TDCP. After optimisation, the platform sends the optimisation results as basis to activation to relevant market operators.
B3	Lack of harmonization of flexibility products for system services for both TSO and DSO	This barrier is tackled by designing common products (e.g., NRT-P-E product, originally based on mFRR requirements can be simultaneously used for balancing and congestion management; or LT-P-C can be used for long-term procurement of capacity for balancing and for congestion management), processes and tools (e.g., FR, TDCP). The Northern demo enables TSOs and DSOs to use flexibility, but also allows the same flexibility to participate on any market.

B7	Limited cross-border coordination/integration	Harmonised cross-border processes, approaches, and products were defined.
B8	Limited coordination for procurement of flexibility by DSO and TSO.	Joint TSO-DSO procurement is organised by the TDCP which is the central point for bid optimisation for all products in the demo. System operators can submit flexibility needs (in case of energy products) and flexibility calls for tender (in case of capacity products) to TDCP, relevant SOs are informed about the flexibility needs and calls for tender which have been submitted by another SO. The demo's product definition mitigates priority use as the products are harmonized and the bid optimisation takes place in the TDCP. The products are cleared sequentially. However, the mitigation of priority use through product definition is currently rather an assumption and may require clear requirements in legal acts in future. The Northern demo allows the same flexibility to participate on any market.
B9a	Lack of alignment in pre-qualification process	The FR tackles the alignment in the pre-qualification process as this is the single point for prequalification. Apart from being a single point for prequalification, the FR can prequalify for any product for which the resource group characteristics are satisfactory. There are two types of prequalification: product prequalification and grid prequalification. Product prequalification means that every resource / resource group can be prequalified only once for the same product (the same product can be used for different services and different buyers). Grid prequalification is agnostic to products.
B9b	Lack of alignment in planning and forecasting (baselining) process	The Northern demo centralises the baselining of different services through the FR. It calculates the ex-post baseline for any product. The ex-post baseline is calculated based on historical consumption data. The demo has been reviewing different baseline calculation methods. The ex-post is used in case the FSP does not provide an ex-ante baseline or in case the FSP has not provided an ex-ante baseline before the deadline. The ex-post baseline methodology used is the adjusted X of Y method. Ex-ante baselines are enabled as an alternative to ex-post baselines. The FR collects the ex-ante baselines from the FSPs. Ex-ante baselines (schedules) are also to be submitted to the FR. The demo does not define exactly which approach needs to be used by who and for which product. Moreover, both approaches can be used in parallel, e.g., for verification purposes by the SO/FR.
B9e	Lack of alignment in settlement process	The FR tackles the alignment in settlement as it is the single point to verify activations. The quantitative settlement (i.e., activation verification) for any product is conducted in the FR. As ex-ante and ex-post baselines are collected there, it is easy to verify product activation.
B10	Lack of established methodology for network representation for the distribution grid	The Northern demo has agreed on a common representation of the grid. The network representation uses network topology (nodes and connections), network limits, network forecasted baseflows and PTDF matrix.
B12	No appropriate baseline methodology and process established for new flexibility markets and new types of flexibility providers (e.g. low voltage flexibility)	The baselining of different services is centralized through the FR. It calculates the ex-post baseline for any product based on historical consumption data. Ex-ante baselines (schedules) are also to be submitted to the FR. The demo has reviewed different baseline calculation methods and will propose a common baseline methodology, i.e., adjusted X of Y. However, the FR is capable to handle different methodologies.
B13	No uniform access and registration	The FR has this task as it is the single point for prequalification.

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	process/platform for assets willing to participate to flexibility markets.	
B17	Unavailability of adequate information allowing FSPs to anticipate the value of their participation and hence not being able to quantify their business case	The Northern demo has touched upon the topic of transparency and trade information sharing, for instance, there is the map UI for flexibility need, and an overview of 'why not realized trades' per area. However, the topic has not been discussed in detail yet.

5.1.3 Czech Republic

The Czech demo is part of the Eastern demo cluster and is implementing market-based DSO coordination. The demo focuses on solving voltage and congestion problems in the distribution network and will also address the problems related to undesirable flows of reactive power in the distribution network that can limit network capacity. To do this, it trades 3 products, namely a predictive short-term local active product for local congestion management of active power, a predictive long-term local reactive product for voltage control by Q management, and a predictive long-term local reactive product for reactive power management. To indicate availability of the DSO for flexibility provision, the demo uses a traffic light system approach. The main objective of the demo is to create a new flexibility market platform to enable the procurement of non-frequency market services as a supporting tool for the DSOs. The demonstration will verify how active and reactive power products can be procured as a marked based product. The traffic light scheme developed as a part of the demonstration will be used for the coordination between the system operators.

The flexibility platform functions as follows: the DSO procures the service at the market platform where it determines location, reserved capacity (MW/MVar), duration of the service and FSP able to deliver requested service. The FSP can indicate their capacities simultaneously in the same environment (market platform). The platform ensures all parties will receive notification about called auctions. Once a relevant offer is accepted by the DSO, the FSP will receive confirmation through the market platform. This amount of flexibility is reported to the dispatch control centre of the relevant DSO – to enable grid planning/scheduling. Relevant units are directed by DSO through the aggregator or directly (who possesses direct control of the flexibility resources). The metering/billing is processed bilaterally between DSO and FSP [64].

The traffic light module has as its objective to signal the availability of the grid for a unit's activation. To achieve this, the DSO reports every unavailability of the distribution grid through an announcement on the grid events, through a dedicated communication tool (i.e., XML messages). The information of grid unavailability is automatically sent through ECP communication to the registered units and FSP, and the system also displays grid unavailability as a traffic light via GUI to the registered units and FSPs [64].

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For more information on the products, services, flexibility platform and traffic light system, please refer to [63], [64].

The overview of the barriers addressed by the Czech demo and their solutions are provided in Table 5-3.

Table 5-3: Overview of addressed barriers and solutions for the Czech demo

No	Barrier	Solution
B2b	Insufficient coordination of different system services over different timeframes for planning and forecasting (baselining)	Aggregators inform DSOs on procured/activated services, which is useful for network planning (see below).
B2c	Insufficient coordination of different system services over different timeframes for procurement	The Czech demo tackles this barrier through their so called 'traffic light scheme' which provides information on the grid availability (see below).
B3	Lack of harmonization of flexibility products for system services for both TSO and DSO	Demo products are fully harmonised, and the platform will be able to accommodate all selected products, i.e., a predictive short-term local active product for local congestion management of active power, a predictive long-term local reactive product for voltage control by Q management, and a predictive long-term local reactive product for reactive power management.
B8	Limited coordination for procurement of flexibility by DSO and TSO.	This barrier is partly addressed by the Czech demo. This entails that aggregators inform DSOs on procured/activated services. The demo's data model uses the identical data infrastructure as the traffic light scheme. Through this IT environment generators send data on activated services to grid operators. This is done 2 weeks ahead and then confirmed day-ahead.
B9c	Lack of alignment in activation process	The Czech demo tackles this barrier through their so called 'traffic light scheme' which provides information on the grid availability. More specifically, grid operators send information on the grid availability to a central place and from there, the information is distributed through a dedicated GUI to all grid users in order to provide them information about if they can/cannot activate their flexibility.
B9e	Lack of alignment in settlement process	The Czech demo provides a database of activated services.
B13	No uniform access and registration process/platform for assets willing to participate to flexibility markets.	The demo has developed a common procedure for the registration of platform users.
B17	Unavailability of adequate information allowing FSPs to anticipate the value of their participation and hence not being able to quantify their business case	FSPs can estimate chances of participation through the traffic light scheme which predicts grid availability. This way FSPs can optimize their portfolio and business case for flexibility provision.

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5.1.4 Hungary

The Hungarian demo is part of the Eastern demo cluster and is implementing market-based DSO coordination. The demo focusses mainly on the problems arising from the high penetration of generation sources (mainly PV) in the MV and LV networks. It uses PV plants as flexibility providers. The demo will focus on congestion management and voltage control through a predictive short term local active product and a predictive short term local reactive product. The main goal of the Hungarian demo is to test how a new flexibility platform can support DSO's in their day-to-day activities and enhance grid operability, taking into account communication and data exchange between DSO and TSO. This will be done through the creation of functional extensions of the flexibility platform for (i) the definition of new potential standardized flexibility services, (ii) the elaboration of related product and grid prequalification processes, (iii) the conceptualisation of location-based service activation, and (iv) the coordination of access to local and system-level services.

Even though the demo is based on a flexibility market structure, it will not be connected to other markets, nor will it have legal and financially binding results for the transaction of flexibility services.

For more information on products, services, the flexibility platform and traffic light system, please refer to [64].

The overview of the barriers addressed by the Hungarian demo and their solutions are provided in Table 5-4.

Table 5-4: Overview of addressed barriers and solutions for the Hungarian demo

No	Barrier	Solution
B9c	Lack of alignment in activation process	A traffic light scheme is developed within the scope of the demo to support activation and avoid cross-activations between assets on the network which are participating both in the DSO flexibility and TSO aFRR market. The traffic light scheme indicates whether DSO-driven activation of an asset is allowed, not allowed, or allowed under certain conditions specified by the TSO.
B10	Lack of established methodology for network representation for the distribution grid	The network representations provided by the DSOs are converted to a common, open-source format. The conversion is carried out by using a data converter that has the custom proprietary data format provided by a DSO as an input. The conversion rules are set up by the help of experts The output of the converter is an open-source format that can be used by the platform logic for network calculations and market algorithms.
B12	No appropriate baseline methodology and process established for new flexibility markets and new types of flexibility providers (e.g. low voltage flexibility)	Baselining is handled via the product design, namely the use of capacity-limitations instead of ordered deviations. More specifically, this means that the demo aims to develop the flexibility product from the connection capacity perspective as a non-firm, interruptible capacity. As a consequence, there are no requirements with regard to baseline because it is not directly connected to the schedule. Of course, there is some forecasting and pre-market network state to predict congestion. The only part where

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		the demo considers some form of baseline is for the consideration or forecast of assets because the network state needs to be estimated. However, for the evaluation of the market and settlement, this approach is much easier as they only need to compare the actual measurement of a connection point that is already measured and then compare this energy measurement to the hourly capacity of the product or reservation of the connecting capability. The only drawback is that it cannot be evaluated whether the change in capacity was on purpose or by accident (e.g., limit PV to zero at night).
B17	Unavailability of adequate information allowing FSPs to anticipate the value of their participation and hence not being able to quantify their business case	The demo uses nested and weighted merit order lists for the quantification of added value; the methodology will be shared with the service providers. The merit order list is formulated based on physical locations on the topology and bid prices. The result can only be shared by the FSP after clearing.

5.1.5 Poland

The Polish demo is part of the Eastern cluster and is implemented as market-based TSO-DSO coordination. The demo focuses on the use of resources connected to the distribution network, mainly from MV and LV levels, to improve the efficiency of the power system. The main objective is to support the TSO in balancing the system and the DSOs in managing congestion in the HV, MV and LV networks and voltage regulation in the MV and LV networks. The demo will focus on congestion management through a predictive short and long term local active product, on voltage control through a predictive short and long term local active energy product, and on balancing (from resources connected to the distribution network) through an mFRR balancing capacity product, an RR balancing capacity product and an active energy balancing product. The goal of the demo is to test how the flexibility services can support the DSO in the network management of HV, MV and LV network and TSO in balancing the system. The demo includes the balancing market as a part of the test and demonstration, but it will be simulated.

The flexibility market platform is based on the new markets for the DSOs needs (congestion management and voltage control) and TSOs needs related to the balancing. For balancing products, an auction will be called by the TSO every day for the day ahead needs (D-1)[19]. Auctions for congestion management and voltage control products will be event-driven, meaning that the DSO will call an auction when a specific situation occurs in the network, this will be day ahead or weeks ahead, depending on the specific situation.

For more information on products, services and the flexibility platform, please refer to [64].

[19] Please note that balancing market behavior is simulated as mentioned in the previous paragraph. Hence, no direct access to the balancing market is foreseen during the demo.

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The overview of the barriers addressed by the Polish demo and their solutions are provided in Table 5-5.

Table 5-5: Overview of addressed barriers and solutions for the Polish demo

No	Barrier	Solution
B8	Limited coordination for procurement of flexibility by DSO and TSO.	To tackle this barrier the demo uses a flexibility platform. This platform enables FSPs to submit bids which in turn can be purchased by the TSO and DSO in a coordinated manner. Bids addressed to CM and VC in the DSO network are submitted and selected before the balancing market cycle (before GCT for balancing capacity) and are taken into account by a dedicated algorithm implemented on the flexibility platform. This algorithm, using network data for a given demonstration area, ensures the optimal selection of balancing offers coming from that area, taking into account the offers previously accepted by the DSO.
B9a	Lack of alignment in pre-qualification process	The demo developed a flexibility platform available to FSPs. This platform ensures uniform access and prequalification (registration) process for all interested parties.
B9b	Lack of alignment in planning and forecasting (baselining) process	The baseline calculation method in the capacity markets is used. There are requirements on a party participating in the Balancing Market that oblige that party to provide the schedule in advance. This schedule is taken as a baseline. In the central dispatch system in Poland, the congestions in the HV and EHV network are released in integrated scheduling process on the Balancing Market. The baseline calculation method is defined in the Regulation available here (in Polish): https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20180001455/O/D20181455.pdf
B10	Lack of established methodology for network representation for the distribution grid	As a part of the project the DSO network is represented with the use of standard KDM model, used in Poland by DSOs and TSO for HV network.
B12	No appropriate baseline methodology and process established for new flexibility markets and new types of flexibility providers (e.g. low voltage flexibility)	The baseline calculation method in the capacity markets is used. The baseline calculation method is defined in the Regulation available here (in Polish): https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20180001455/O/D20181455.pdf
B13	No uniform access and registration process/platform for assets willing to participate to flexibility markets.	The demo developed a flexibility platform available to FSPs. This platform ensures uniform access and prequalification (registration) process for all interested parties.

5.1.6 Slovenia

The Slovenian demo is part of the Eastern cluster and is implemented as market-based DSO coordination. The demo is focusing on solving problems locally in the LV networks. The main problems are the overload of the MV/LV transformers and power lines and voltage violations in the LV networks. The flexibility is procured from aggregated demand response (from household heat pumps, EVs, etc.). The Slovenian demo will focus both on congestion management and voltage control through the use of a predictive short term local active product. The main objective of the demo is to test how local flexibility based on the demand side management can be used by the DSO to solve problems in the LV network. This is done through the development and deployment of a market platform for DSO services. On this platform, two different services are tested in a productive environment: congestion management and voltage control. The demo aims to run the selected services in a real market environment with real prices for activated energy.

For more information on products, services and the flexibility platform, please refer to [64].

The overview of the barriers addressed by the Slovenian demo and their solutions are provided in Table 5-6.

Table 5-6: Overview of addressed barriers and solutions for the Slovenian demo

No	Barrier	Solution
B3	Lack of harmonization of flexibility products for system services for both TSO and DSO	The demo tackles this barrier by following good practices from TSO market rules when they are defining new DSO products. The new DSO products are similar to products already used by the TSOs.
B9c	Lack of alignment in activation process	At the start of the demonstration, the demos were using a manual activation process (via telephone call) which has now evolved to ICT connections for automatic activations, which allows to expand such services to multiple locations if needed. A file structure identical to that of the TSO is used for activations, only the infrastructure through which those files are delivered is different from the TSO infrastructure. The demo uses the same common information model and the same XML files for activation.
B9e	Lack of alignment in settlement process	The demo uses the same formulas for calculating activated energy according to effective power and baseline.
B12	No appropriate baseline methodology and process established for new flexibility markets and new types of flexibility providers (e.g. low voltage flexibility)	The baseline methodology follows good practices from the TSO market. The methodology for DSOs uses the last 15min interval effective power before activation announcement as the baseline (from the measurements), whereas the TSO use the last schedule sent before activation (which is a bit of extra work for similar result, as the last schedule sent reflects effective power 15 min before activation).
B13	No uniform access and registration process/platform for assets willing to participate to flexibility markets.	These processes reflect good practices from the TSO market. A platform for uniform registration process was created in the process. Since the target audience is different, it is not expected for the process to become one with the processes used by the TSO.
B17	Unavailability of adequate information allowing FSPs to anticipate the value of their participation and hence not being able to quantify their business case	All locations are studied in advance with historical data, so that the expected number of activations (and activated energy) can be anticipated. In the future, the DSO will publish a tender for different locations. The total flexible power of each location will be given, but not expected number of activations or total time of activations.

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5.1.7 Cyprus

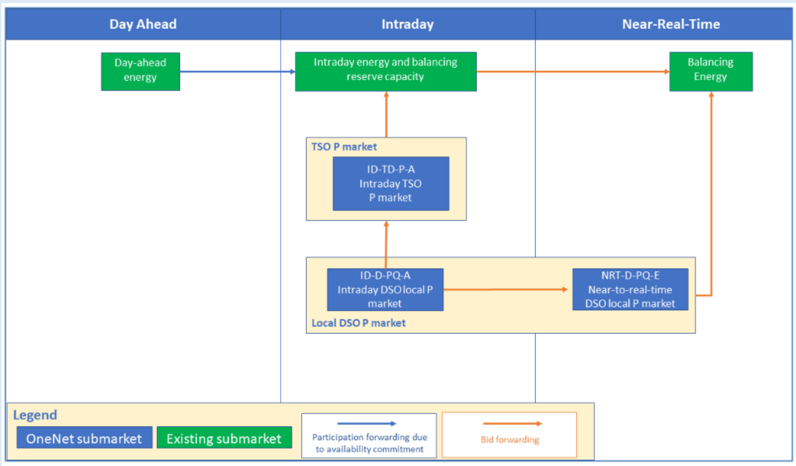
The Cypriot demo is part of the Southern cluster and implements market-based TSO-DSO coordination. The demo focuses on congestion management, voltage control, frequency control and active power management, and trades a corrective local reactive product. It aims to demonstrate an effective collaboration between the different actors of the Cypriot power system namely the TSO, DSO, Market Operator, and prosumer/aggregator. The Cyprus demo will, among other things, (i) allow aggregators and prosumers to provide active power, reactive power and power quality flexibility services to the power grid, (ii) enable higher penetration of RES without risking the stability and integrity of the system, and (iii) showcase that the effective collaboration of the critical actors of the power system through the OneNet System can benefit the grid. The demo will set up a market architecture that will include a local DSO ancillary services market which will handle the congestion management of the distribution grid and a central TSO ancillary services market that will deal with the frequency containment reserve. It will develop two platforms: the Active Balancing and Congestion Management platforms for the DSO and the TSO, ABCM-D and ABCM-T respectively.

More information on products, services, and platforms can be found in [63], [65].

The overview of the barriers addressed by the Cypriot demo and their solutions are provided in Table 5-7.

Table 5-7: Overview of addressed barriers and solutions for the Cypriot demo

No	Barrier	Solution
B1	Insufficient coordination of flexibility markets for system services with energy markets with regard to timing.	The flexibility services regarding the frequency support (W/Hz) are cleared in the TSO intra-day market, while the local congestion management services regarding the active power (W) are cleared in the DSO local near real time market (see figure below, taken from [63]). The reactive power support provided for the local congestion is considered independently from the active power support and there is no need for timing co-ordination. It should be noted that there is not any existing operational market in Cyprus yet. In the demo (where the market virtual), the TSO intra-day market will be cleared every three hours while the DSO local near real time market will be cleared every hour.



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B3	Lack of harmonization of flexibility products for system services for both TSO and DSO	As a solution, the flexibility products are well harmonized and decoupled between them. This means that the products are not creating conflicts between them. For instance, in this demo the TSO intraday market deals with the frequency support products. Hence, frequency support products (e.g., rapid active power change according to frequency) provided by FSPs in both transmission and distribution level bid only for frequency support products in the TSO intraday market. On the contrary, in the DSO local market, the products that are provided are related to the congestion management (e.g., change of active power, phase balancing, change of reactive power).
B8	Limited coordination for procurement of flexibility by DSO and TSO.	The barrier in the Cypriot demo is related to the use of different products (with different attributes) to solve one grid problem (e.g., congestion management). This barrier is addressed by the development of an optimal algorithm for the activation of multiple products (by the DSO) to minimize the grid cost according to the market prices of the different products. The algorithm defines an analytical solution for the activation of multiple products at each time step to solve the congestion. For example, in case that two different products are available for congestion management (e.g. the phase balancing reduction of active power and reactive power products) with two different prices, the algorithm will activate the combination of the products that can achieve congestion relief at the minimum cost. Additionally, as mentioned before, the flexibility products are well harmonized and decoupled between them. The products related to the phase balancing and reactive support are decoupled (as they provide a different kind of service) from the FCR products and active power products. In the case of the harmonized FCR and active power products, the FCR products are first cleared on the TSO intra-day market while the remaining active power flexibility (from the FSPs in the distribution grid) can be traded in the local DSO near real time market. In this sense, the TSO has priority for this type of products. Moreover, the FSPs are able to provide multiple services to increase their value stacking.
B9a	Lack of alignment in pre-qualification process	In the Cyprus demo, this barrier is encountered for the TSO products (e.g., FCR) when they are provided by FSPs at the distribution grid. The barrier is tackled by having a prequalification scheme that takes into account the distribution grid constraints (technical prequalification only without considering different timeframes) for the provision of flexibility services by FSPs. This prequalification defines the limits of the TSO-DSO interconnection point that will not cause any operation limits violation. These limits are forwarded to the TSO market to be considered during the clearing of the FCR products offered by the FSPs.
B10	Lack of established methodology for network representation for the distribution grid	The demo considers full knowledge about the distribution grid model and monitoring schemes for operating condition visualization. The monitoring scheme that was developed for representing the operating condition of the grid is based on the weighted least squares approach. This approach uses power injection, power flow measurements, smart meter measurements, as well as the grid topology to estimate in consecutive time intervals the voltage magnitude and angle in all the nodes of the distribution grid. This information can be further used in assessing the operating condition of the grid and help in the decision making of the DSOs. It is assumed that all feeders are monitored both in the MV and LV levels, or at least the active and reactive power flow at the beginning of each

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		feeder is available through measurements. The operating conditions of the FSPs are also available in real time.
B12	No appropriate baseline methodology and process established for new flexibility markets and new types of flexibility providers (e.g. low voltage flexibility)	In the demo, the identification of the baseline operation of the low voltage consumer is a critical aspect to allow the proper remuneration of the consumer in the case of flexibility provision. The LV prosumer that participates in the congestion management separates the loads into controllable and uncontrollable loads under two different smart meters. The demo deploys a load/generation forecasting scheme applied only to the controllable loads to provide short term forecasting, at the prosumer side. The forecasting errors that are calculated by the FSPs (according to the deviation between the forecasting profile of the controllable loads and the actual demand) are corrected by using an energy storage system (owned by the prosumer and connected under the controllable load meter) to ensure that the consumers are able to track the predefined power exchange profile of the controllable loads.
B13	No uniform access and registration process/platform for assets willing to participate to flexibility markets.	The demo has developed uniform interfaces for the FSPs to submit their offers for different services procured in different markets.

5.1.8 Greece

The Greek demo is part of the Southern cluster and is implementing technical based TSO-DSO coordination on the existing market architecture. The demo targets congestion management and voltage control and trades 3 products, namely a predictive short-term local active product, a predictive long-term local active product, and a corrective local reactive product. The main goal of the demo is to improve the procedures for congestion management resolution. This will be done through the "TSO-DSO Flexibility Channel" (F-Channel) which is a digital platform for providing grid services (frequency and non-frequency) for the balancing and congestion management challenges. It demonstrates the setting-up of a flexibility market with various common products for TSO-DSO coordination. The core technologies of the digital platform are (i) the forecasting module (ensuring predictability of the highly volatile RES generation and demand) and (ii) the coordination module, which will consider the existing functionality and data of key systems (e.g., the control system, asset register, GIS). Both modules will consider all the various stakeholders participating in existing or near future markets in Greece, including prosumers, aggregators, storage owners, and EV charging station operators [65].

More information on products, services, and platforms can be found in [63], [65].

The overview of the barriers addressed by the Greek demo and their solutions are provided in Table 5-8.

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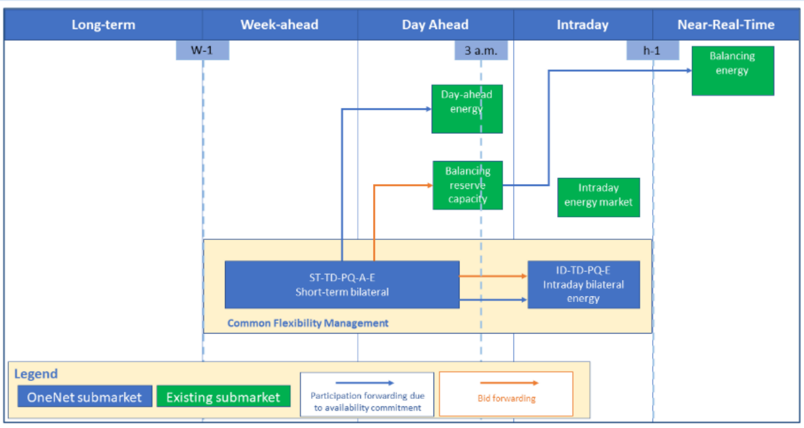
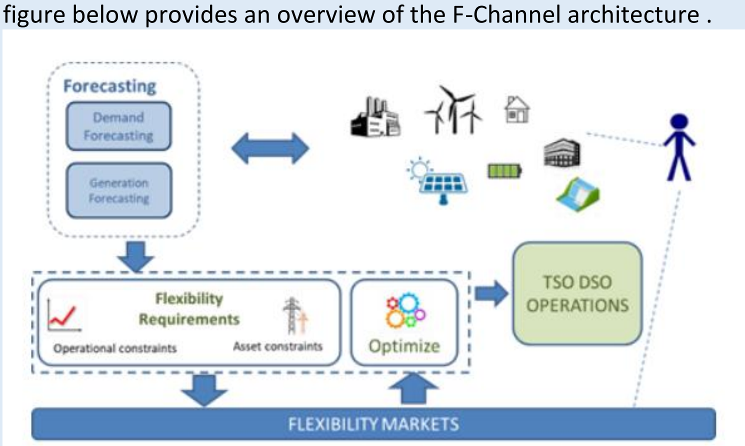
Table 5-8: Overview of addressed barriers and solutions for the Greek demo

<table>
<tr><th>No</th><th>Barrier</th><th>Solution</th></tr>
<tr><td>B1</td><td>Insufficient coordination of flexibility markets for system services with energy markets with regard to timing.</td><td>The Greek demo solves this barrier by means of the market structure. It foresees coordination between the already existing Greek markets (DAM and IDM as wholesale markets and balancing markets) and the implemented flexibility platform, called F-channel. This sequence is chosen in order not to violate the current, already running market design in Greece.


F-channel is foreseen as a web based, client server application which will enhance Active Power Management for TSO-DSO coordination using Artificial Intelligence methods and cloud-computing approach [65]. The platform operates in parallel timeframes and provides availability bids to the existing markets.
The F-channel is implemented as a separate flexibility platform and market that exchanges information with the existing markets and forwards bids to the markets that work near real time. Currently, there are rules for considering flexibility bids within the balancing market rulebook. Until now, all available RES quantities are activated within the existing sequence of markets. Therefore, the forecasted RES and load time series can be provided as inputs to the existing markets in order to consider them.
The figure below provides an overview of the F-Channel architecture [66].The figure below provides an overview of the F-Channel architecture .

</td></tr>
<tr><td>B2b</td><td>Insufficient coordination of different system services over different timeframes for</td><td>The F-Channel has a forecasting module that provides both short-term and long-term forecasts for both weather and flexibility volumes. It is a tool designed and implemented to be used by system operators.</td></tr>
</table>

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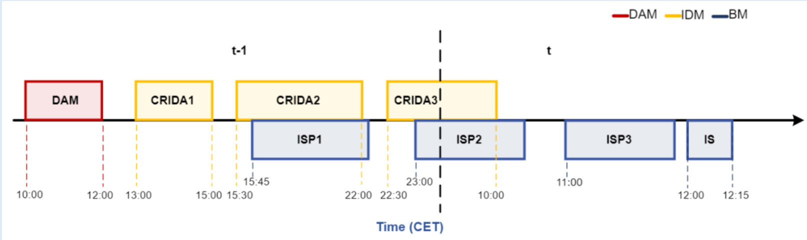
	planning and forecasting (baselining)	
B2c	Insufficient coordination of different system services over different timeframes for procurement	The existing market (DAM, IDM, and BM) timeframes are provided in the figure below. The calculated availability bids of the FSPs will be forwarded from the F-Channel to all the different market timeframes, meaning that FSPs can participate in all the considered market segments. 
B2d	Insufficient coordination of different system services over different timeframes for activation	The unified platform, developed within the demo, should enhance the coordination between the participants in the flexibility market. Tn the first place, the F-channel provides the forecasts. These are forwarded to the existing sequence of markets and are taken into account. The sequence of markets results in a schedule for the assets that have to be activated which is forwarded to the F-channel. The latter sends the activation signals to the FSPs that are connected and provided bids in F-channel in the first place. Some hierarchy rules are considered in order to coordinate the participants.
B2e	Insufficient coordination of different system services over different timeframes for monitoring	This platform will, together with all of its modules such as the forecasting module, be interconnected both to the system operators and to the customers, allowing for any potential issue regarding the coordination to be resolved in a fast and efficient manner. This also includes the problems related to the different timeframes for monitoring purposes.
B3	Lack of harmonization of flexibility products for system services for both TSO and DSO	The demo uses TSO products for balancing, voltage control, and congestion, and DSO products for voltage control and congestion. The products for voltage control and congestion have the same product attributes and values for TSO and DSO.
B8	Limited coordination for procurement of flexibility by DSO and TSO.	The F-channel, via its coordination module, enhances the coordination between the TSO and the DSO. The F-channel communicates the requirements and availability to the SOs and the connected FSPs, based on the forecasted results.
B9a	Lack of alignment in pre-qualification process	The flexibility platform acts as a solution here. Within the F-channel, technical prequalification of the FSP assets can be done once within the registration of each FSP. The solution offered by the demo is the creation of a common flexibility register (within the F-Channel) that contains the location of the FSPs resources and other necessary eligibility criteria that assist in the (grid asset technical) prequalification process.
B9b	Lack of alignment in planning and forecasting	The forecasting module of the implemented F-channel provides realistic assessments of the weather conditions and gives, based on these forecasts, appropriate dispatch setpoint instructions for the FSP assets.

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	(baselining) process	
B9c	Lack of alignment in activation process	Priority will be given accordingly to TSO or DSO depending on the product and the issue that should be resolved by it.
B12	No appropriate baseline methodology and process established for new flexibility markets and new types of flexibility providers (e.g. low voltage flexibility)	Currently, there is a common baseline load calculation within the balancing market. The methodology is provided here: https://www.admie.gr/sites/default/files/users/dda/KAE/Baseline%20methodology_v3.pdf Short description Dispatchable Load Portfolio Baseline mFRR: The estimated volume of electricity that would have been consumed from the Dispatchable Load Portfolio, in the event that the Demand Response Event had not occurred, constitutes the Dispatchable Load Portfolio Baseline. mFRR Baseline Load Calculation Methodology For a Dispatchable Load Portfolio to participate in the Balancing Market, the Demand Response Aggregator has the right to choose one of the available methods for calculating the Dispatchable Load Portfolio Baseline. The available methods for calculating Dispatchable Load Portfolio Baseline are the method internationally-known as the 'Meter before-Meter after' and the ‘High X of Y’ method. Meter Before-Meter After' Method Under the baseline load calculation method 'Meter Before-Meter After', in the case of issue of a Dispatch Order for the provision of upward or downward mFRR Balancing Energy or energy for purposes other than balancing (reduction or increase of load respectively), the baseline load is equivalent to the sum of the certified reduced metered quantities absorbed at the Transmission System/Distribution Network Boundary, for the entire Dispatchable Load Portfolio during the Imbalance Settlement Period prior to the Demand Response Event. High X of Y Method Under the baseline load calculation method “High X of Y”, from the eligible days Y, X days with the highest consumption are selected and the Initial Dispatchable Load Portfolio Baseline is calculated on the basis of recent metered measurements of load consumption during those days. Furthermore, for the calculation of the highest consumption the average method is used, as shown below. mFRR Dispatchable Load Portfolio Baseline for Intermittent RES Generation Units The Dispatchable Load Portfolio Baseline for Intermittent RES Generation Units is defined as the electricity that would have been produced from the Portfolio of Dispatchable Intermittent RES Generation Units in the event that it had not received a Dispatch Instruction activating a mFRR Balancing Energy Offer from the HETS Operator. mFRR Baseline Load Calculation Methodology: 'Meter Before-Meter After' Method To calculate the Baseline Load under the Baseline Load Calculation Method 'Meter Before-Meter After', the certified 15-minute metered measurements before and the certified 15-minute measurements after one or more consecutive

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		Dispatch Instructions activating mFRR Offers (upward or downward) sent to a Dispatchable Portfolio of Intermittent RES Generation Units. <u>aFRR Baseline Load</u> The method presented in this section is used to determine the activated aFRR Balancing Energy for the Dispatchable Load Portfolios and the Dispatchable Portfolio of Intermittent RES Generation Units. The aFRR Baseline Load of a Portfolio is defined as the electricity that would have been produced/consumed by the Portfolio in the event that it had not received a Dispatch Instruction for the activation of an aFRR Balancing Energy Offer from the HETS Operator. <u>Declaration Method</u> The aFRR Baseline Load is calculated by the Aggregator for each cycle of the aFRR process, i.e. every four (4) seconds, and is sent by the Aggregator to the HETS Operator via a remote terminal unit (RTU) one (1) minute before each cycle of the aFRR process. For example, at 14:00:00 (hh:mm:sd) the Aggregator sends the portfolio' production/consumption in MW for the period 14:01:00 – 14:01:04. Next, at 14:00:04 (hh:mm:sd) the Aggregator sends the portfolio's production/consumption in MW for the period 14:01:04 – 14:01:08 and so on.
B13	No uniform access and registration process/platform for assets willing to participate to flexibility markets.	This issue is resolved via the F-channel flexibility registry. It provides the same registration format for all assets.
B17	Unavailability of adequate information allowing FSPs to anticipate the value of their participation and hence not being able to quantify their business case	The forecasting module of the F-channel provides realistic assessments of the weather conditions and gives, based on the forecasts, an appropriate value for the required flexibility volumes. This value is shared with the FSPs as well.

5.1.9 France

The French demo is part of the Western cluster and is implementing technical based TSO-DSO coordination. It aims at building a blockchain-based platform shared by TSO DSO and producers, in order to simplify and optimize the compensation of producers after a flexibility activation. The so-called STAR platform will enable the tracking and sharing of data related to the entire life cycle of a flexibility activation, from the order submission to the compensation of the producer.

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The overview of the barriers addressed by the French demo and their solutions are provided in Table 5-9.

Table 5-9: Overview of addressed barriers and solutions for the French demo

No	Barrier	Solution
B9d	Lack of alignment in monitoring process	The demo's STAR platform will have the participants rely on a unique source of monitoring data, eventually easing the settlement process. These monitored data are mostly activation orders, metered active power and estimated energy not served during the activation period. The data will be registered on the STAR platform within one or two months after being received. The data are needed to check that the producers adapted their production according to the activation and compute their financial compensation. Having information stored on a shared ledger will ease the settlement process by ensuring the unicity of data and transparency for each participant (lesser risk of dispute).
B13	No uniform access and registration process/platform for assets willing to participate to flexibility markets.	The demo's STAR platform will enable a standardized user journey for producers willing to participate.

5.1.10 Portugal

The Portuguese demo is part of the Western cluster and is implementing technical based TSO-DSO coordination. The demo will focus on congestion management through a predictive local short-term and local long-term active product. The main goal is to test a data exchange information mechanism between the Portuguese DSO and TSO for flexibility and operational planning purposes. More specifically, it will test the processes for DSO-TSO data exchange and storage related to: (i) the pre-qualification processes, considering both grid and product pre-qualifications; (ii) the identification of daily flexibility needs to prevent congestions in the distribution and transmission networks; (iii) the annual maintenance plans, including monthly and weekly updates of the existing plans; (iv) the daily consumption and generation forecasts; (v) the daily forecasted short-circuit information.

More information on products, services and the exchange mechanism can be found in [63], [67].

The overview of the barriers addressed by the Portuguese demo and their solutions are provided in Table 5-10.

Table 5-10: Overview of addressed barriers and solutions for the Portuguese demo

No	Barrier	Solution
B2a	Insufficient coordination of different system services over different timeframes for pre-qualification	Time windows were defined for the different stages and interactions between the DSO and TSO.
B2b	Insufficient coordination of different system services over different timeframes for planning and forecasting (baselining)	Time windows were defined for the different stages and interactions between the DSO and TSO in order to be aligned with the gate closure times of the existing markets

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B7	Limited cross-border coordination/integration	The demo is using the OneNet Connector to test cross-border information exchange between the DSO, the TSO and the foreign system operator for prequalification purposes, allowing an FSP that is connected to one system (either distribution or transmission level), to be prequalified across-borders.
B9a	Lack of alignment in pre-qualification process	One of the System Use Cases of the demo aims to align and test the data and information flows between the DSO and the TSO, considering two different scenarios: (1) prequalification for FSPs connected to the distribution grid, considering both the situation where the FSP wants to be prequalified by the TSO and the situation where it wants to be prequalified by the DSO; (2) prequalification of FSPs connected to the transmission grid, considering both the situation where the FSP wants to be prequalified by the DSO and the situation where it wants to be prequalified by the TSO. For example, in the case where the FSP is connected to the distribution grid: (i) if they want to be prequalified by the TSO, the TSO will inform the DSO and request a grid prequalification from its side; (ii) if they want to be prequalified by the DSO, the DSO will only inform the TSO of the prequalification result, and the process ends with an acknowledgement (or not) from the TSO. To guarantee a smooth and effective interaction, the format and schema of the information shared is defined and validated within the data exchange process. The results of the prequalification are stored on both sides, DSO level and TSO level, so no common database for storing information is tested.
B9b	Lack of alignment in planning and forecasting (baselining) process	One of the System Use Cases of the demo will test the data exchange between the DSO and the TSO so that they can determine how much flexibility they will need to acquire for a short-term time frame (day-ahead and intraday). This coordination is needed to prevent congestions in the distribution and transmission grids due to the activation of active power flexibilities for the needs of the TSO and DSO. This SUC defines and tests the steps that SOs should follow to identify potential network restrictions for the next day and intraday and to understand the amount of flexibility they will need to solve their needs and constraints. To determine the flexibility needs, the following aspects will be considered: grid layout, weather forecasts and information on the flexible assets.
B13	No uniform access and registration process/platform for assets willing to participate to flexibility markets.	The Portuguese demo accounts for a continuous synchronization of the registry from both DSO and TSO side, thus opting for a distributed registry instead of a centralised one, so that there will not be a single entity managing the registry database. The demo does not address the perspective of the FSP in the registry but is solely focused on the information flow between DSO and TSO.

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5.1.11 Spain

The Spanish demo is part of the Western cluster and is implementing market-based DSO coordination. It is focused on congestion management and trades a predictive short-term local active, a predictive long-term local active and a corrective local active product. The objective is to use the flexibility of the resources connected to the distribution system to manage congestion at the distribution level. To enable the trading of flexibility products, a local market platform is developed in which the DSOs can buy flexibility services from FSP in two main submarkets: (i) Long-term market: long term procurement of flexibility services through a market mechanism to avoid congestions at the medium or low voltage distribution networks, and (ii) Short-term market: short term procurement of flexibility services through a market mechanism to avoid congestion management at the medium or low voltage distribution network, the day ahead or intraday.

More information on products, services and the exchange mechanism can be found in [63], [67].

The overview of the barriers addressed by the Spanish demo and their solutions are provided in Table 5-11.

Table 5-11: Overview of addressed barriers and solutions for the Spanish demo

No	Barrier	Solution
B12	No appropriate baseline methodology and process established for new flexibility markets and new types of flexibility providers (e.g. low voltage flexibility)	The baseline methodology is based on historical data information. Currently, there is no specific rule for baseline calculation. Therefore, the demo is studying different ways to calculate the baseline using historical information from smart meters or asset monitoring devices.

5.2 Mapping of demo solutions to OneNet solutions

In this section, a mapping of the different solutions developed in OneNet demonstrators is done, linking all the solutions with the barriers listed in Section 4.3 above and categorising the solutions into three category spaces: market process, technical solutions for SOs and market access. After the categorisation, an analysis of the solutions implemented by the demos within each category space is performed to identify similarities across solutions adopted and major differences among them.

5.2.1 General overview

Table 5-12 maps the different solutions identified and developed by the demos and links them with the barriers listed under Table 4-3. This mapping comprises of responses gathered from the demos that are thoroughly described in section 5.1. The solutions are colour coded, representing the category space where the solution fits best.

The category on "Market processes" (yellow) comprises solutions adopted by the demos towards the optimisation of market procedures, addressing aspects such as gate closure coordination among different markets, harmonisation of products exchanged in the markets and the different methods adopted for baselining and settlement. The "Technical solutions for SOs" category (green) includes several solutions implemented by SOs to promote coordination on flexibility procurement by DSOs and TSOs, aligning time windows and information flows within and across borders, developing accurate forecasting solutions to identify the needs, together with bid optimisation tools and common models for grid representation. The category on "Market access" (orange) includes solutions to improve market access and promote increased participation by different FSPs in flexibility markets.

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Table 5-12 – OneNet demo solutions mapping

Barrier	Northern	Czech	Hungary	Poland	Slovenia	Cyprus	Greece	France	Portugal	Spain
B1 -Insufficient coordination of flexibility markets for system services with energy markets with regards to timing.	Coordinate gate closure times	-	-	-	-	Market division based on service provided	Coordination markets / F-Channel	-	-	-
B2A - Insufficient coordination of different system services over different timeframes for pre-qualification	Flexibility Register	-	-	-	-	-	-	-	Align time windows	-
B2B - Insufficient coordination of different system services over different timeframes for planning and forecasting (baselining)	-	Traffic light scheme	-	-	-	-	F-Channel forecasting module	-	Align time windows	-
B2C - Insufficient coordination of different system services over different timeframes for procurement	Products sold in sequential markets in terms of gate closure	Traffic light scheme	-	-	-	-	Availability bids forwarded from F-Channel to all market timeframes	-	-	-
B2D - Insufficient coordination of different system services over	Optimisation of results	-	-	-	-	-	Forecasts forward from F-	-	-	-

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different timeframes for activation	through TDCP						Channel to market sequence			
B2E - Insufficient coordination of different system services over different timeframes for monitoring	-	-	-	-	-	-	F-Channel connecting consumer/ SO	-	-	-
B2F - Insufficient coordination of different system services over different timeframes for settlement	-	-	-	-	-	-	-	-	-	-
B3 - Lack of harmonization of flexibility products for system services for both TSO and DSO	Design of common products	Fully harmonized products	-	-	New DSO products similar to products used by TSOs	Fully harmonized products	Harmonised product attributes	-	-	-
B4 - Exclusivity clauses and non-harmonised contracts	-	-	-	-	-	-	-	-	-	-
B6 - No specific incentives in the regulatory mechanism (remuneration) that support a common approach between SOs for flexibility procurement	-	-	-	-	-	-	-	-	-	-
B7 - Limited cross-border coordination/integration	Harmonised cross-border processes	-	-	-	-	-	-	-	OneNet Connector for cross-border	-

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	and products[20]								data exchange	
B8 - Limited coordination for procurement of flexibility by DSO and TSO	Joint procurement through TDCP	Traffic light scheme	-	Flexibility platform	-	Algorithm for multiple product activation	F-channel coordination module	-	Align information flows on flexibility needs	-
B9A - Lack of alignment in pre-qualification process	Flexibility Register	-	-	Flexibility platform – uniform prequalification	-	DSO constraints considered in the TSO prequalification	Common flexibility register within F-channel	-	Align information flows on prequalification	-
B9B - Lack of alignment in planning and forecasting (baselining) process	Flexibility Register	-	-	Baselining method used in capacity markets	-	-	Dispatch setpoints based on F-channel forecasts	-	Align information flows on flexibility needs	-
B9C - Lack of alignment in activation process	-	Traffic light scheme	Traffic light scheme	-	ICT connections for automatic activations	-	Priority dependent on the product/ issue	-	-	-
B9D - Lack of alignment in monitoring process	-	-	-	-	-	-	-	Unique source of monitoring data	-	-

[20] This solution is quite wide in scope and can fit in either one of the categories, although, for categorisation purposes the most prominent one was considered: market processes. Nonetheless, the processes can also fit in the market access, through the use of the flexibility register for prequalification, and under technical solutions, through the TDCP.

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B9E - Lack of alignment in settlement process	Flexibility Register	Database of activated services	-	-	Same formulas as for a activated energy based on effective power/ baseline	-	-	-	-	-
B10 - Lack of established methodology for network representation for the distribution grid	Common grid representa tion	-	Common open-source format	Standard KDM model	-	Full knowledge on grid model and monitoring schemes	-	-	-	-
B12 - No appropriate baseline methodology and process established for new flexibility markets and new types of flexibility providers (e.g. low voltage flexibility)	Flexibility Register	-	Based on capacity-limitations instead of ordered deviations	Baselining method used in capacity markets	Good practices from the TSO market	Forecastin g scheme for controllabl e loads	Common baseline load calculation	-	-	Based on historical informatio n
B13 - No uniform access and registration process/platform for assets willing to participate to flexibility markets	Flexibility Register	Common procedure for users' registry	-	Flexibility platform - uniform access	Good practices from the TSO market	Uniform interfaces for the FSPs	F-channel flexibility registry	Standardise d user journey through STAR platform	Synchroniz ation of DSO and TSO databases	-
B14 - Risk of gaming due to exertion of market power and/or shortcomings in the market setting	-	-	-	-	-	-	-	-	-	-

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B17 - Unavailability of adequate information allowing FSPs to anticipate the value of their participation and hence not being able to quantify their business case	Map UI for flexibility need overv iew of 'why not realized trades' per area	Traffic light scheme	Weighted merit order lists	-	Studies in advance to anticipate nº of activations	-	Accurate required flexibility based on F-channel forecasts	-	-	--

Figure 5-2 below presents the distribution of the category spaces among the solutions implemented by the demos, showing a balanced split between the solution spaces identified.

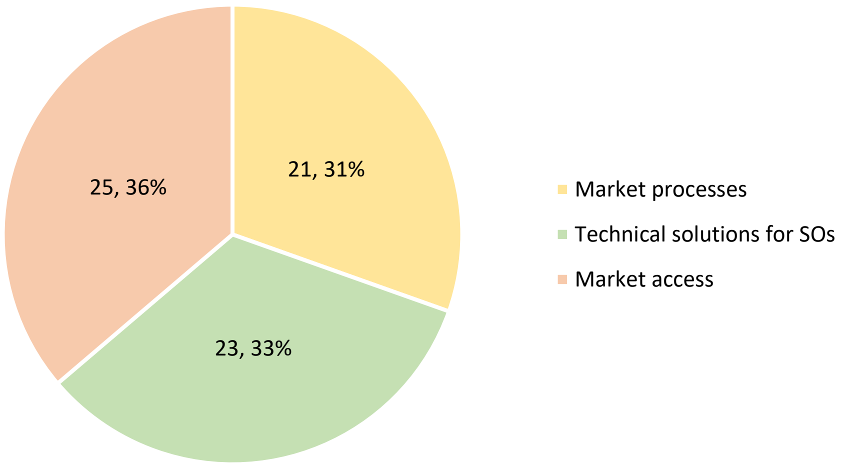

Figure 5-2 - Percentage distribution of the category spaces across the demo solutions

5.2.2 Market processes

The “Market processes” category covers the main solutions implemented by the OneNet demos to optimise or even create new market procedures, mainly addressing barriers related to the lack of harmonisation of flexibility products for system services for both TSO and DSO (B3) and to the non-existence of appropriate baseline methodology and process established for new flexibility markets and new types of flexibility providers (B13). It’s important to note that some solutions can serve both market processes and market access, hence, solutions related to prequalification, such as the implementation of a flexibility register could well be included in this category but were categorised as a “market access” solution.

There were three main solutions implemented by the demos, these being: (1) gate closure coordination; (2) Harmonised products; and (3) Baselining methods. A generic description of these “macro” solutions can be found in Table 5-13, Table 5-14 and Table 5-15 respectively, along with a more concrete description with examples from the demos, and identification of main similarities and differences in the implemented solutions.

Table 5-13 – Generic description of the “macro” solution on gate closure coordination

(1) Gate closure coordination		
Generic description	**Barriers addressed**	**Demos**
Coordinate gate closure times of flexibility markets with existing energy markets (intraday), to better estimate network state and flexibility needs to be accommodated by flexibility products that are subsequently activated	B1 - Insufficient coordination of flexibility markets for system services with energy markets with regards to timing B2c - Insufficient coordination of different system services over different timeframes for procurement B8 - Limited coordination for procurement of flexibility by DSO and TSO	Northern, Polish, Cypriot, Greek

A concrete example for this “macro” solution is provided by the Northern demo, which uses the same gate closure time for short-term active energy product (ST-P-E) as in the intraday market, and the near real-time active energy product (NRT-P-E) will come 2 hours after, i.e., close to real time. This is done in order to have full knowledge of the network flows after the activation of the ST-P-E products, thus optimising the use of NRT-P-E products. Also, energy products are sold in sequential markets in terms of gate closure.

The Polish demo chooses a different approach, establishing that all bids related to congestion management and voltage control for the distribution grid are submitted and selected before the gate closure time for balancing capacity, and are taken into account by a dedicated optimisation algorithm embedded in the Flexibility platform. The opposite approach is foreseen in the Cypriot demo for FCR products, which are first cleared in the TSO intraday market while remaining active power flexibility from FSPs connected in the distribution grid can be traded afterward, in the local DSO near real-time market, thus, giving priority to the TSO to access this type of products.

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Coordinating existing markets with newly developed technology platforms is something foreseen by the Greek demo, where the F-Channel platform operates in parallel timeframes and provides availability bids to existing markets.

Table 5-14 - Generic description of the "macro" solution on harmonised products

(2) Harmonised products		
Generic description	**Barriers addressed**	**Demos**
Design common and harmonised products and product attributes that can be accommodated in the market platforms and are decoupled to avoid any conflicts.	B1 - Insufficient coordination of flexibility markets for system services with energy markets with regards to timing B3 – Lack of harmonization of flexibility products for system services for both TSO and DSO B7 - Limited cross-border coordination/ integration	Northern, Czech, Slovenian, Cypriot, Greek

The "macro" solution on common and harmonized products is widely implemented by OneNet demos. The Czech demo, for instance, ensures that its platform can accommodate all the selected harmonised products, namely, a predictive short-term local active product for local congestion management of active power, a predictive long-term local reactive product for voltage control by Q management, and a predictive long-term local reactive product for reactive power management. The Northern demo addresses near real-time active products and long-term capacity products (NRT-P-E and LT-P-C), the first can be used for balancing and congestion management, and the second can be used for long-term procurement of capacity for balancing and congestion management. The Northern demo also foresees that these common products can be trade across borders.

For designing these harmonised products, OneNet demos rely frequently on existing best practices from TSO markets, namely, the Northern demo originally based its NRT-P-E product on mFRR requirements. Ensuring a clear decoupling of the products is also of concern by several OneNet demos to avoid any market conflicts, for instance, the Cypriot demo defines that TSO intraday market deals with frequency support products, whereas congestion management products are provided in the DSO local market. However, the Greek demo foresees some intersection between the products, foreseeing TSO products for balancing, voltage control and congestion management, and DSO products for voltage control and congestion, assuming the same attribute values for voltage control and congestion management products for TSOs and DSOs.

Table 5-15 - Generic description of the "macro" solution on baselining methods

(3) Baselining methods		
Generic description	**Barriers addressed**	**Demos**
Establish a concrete method to define the baseline, either via historical data or accurate	B9b – Lack of alignment in planning and forecasting (baselining) process	Northern, Hungarian, Polish, Slovenian,

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load/generation forecasting, or even via product design	B12 - No appropriate baseline methodology and process established for new flexibility markets and new types of flexibility providers (e.g., low voltage flexibility)	Cypriot, Greek, Spanish

This "macro" solution addresses one usual barrier related to flexibility markets, which is the actual and accurate definition of a baseline to verify flexibility services provision. It is in fact one aspect targeted by several demos, with different approaches being followed. Both the Northern and Spanish demos rely on historical data information to define the baseline, with the latter haven't yet defined specific rules for baseline definition but is currently undergoing some studies on different ways to calculate the baseline using historical information from smart meters or asset monitoring devices. However, the Northern demo foresees two different approaches for baseline calculation, either ex-ante provided by the FSP, or ex-post baseline, the latter based on historical data and centralises this process via its flexibility register, through which the settlement process is also done. The Northern demo resorts to the ex-post process in case the FSP doesn't provide an ex-ante baseline until the predefined deadline.

Forecast-based solutions are also implemented. In the Cypriot demo LV prosumers separate loads between controllable and uncontrollable, having two different smart meters installed, for each of these categories, and a load/generation forecasting scheme is applied solely to the controllable loads, for which forecasting errors calculated by the FSPs are corrected by a storage system installed by the prosumer. The Greek demo relies on its F-Channel to do realistic assessments of weather conditions and based on that, provides dispatch setpoint instructions for FSPs, and uses the common baseline load calculation provided for in the existing balancing market. The Slovenian and Polish demos also adopt similar practices done in TSO markets, with the latter using the same baselining method used in capacity markets. The Hungarian demo adopts a different approach from other demos, addressing the baselining barrier via product design, namely through the use of capacity limitations instead of ordered deviations, thus, no requirements are defined in the demo regarding baseline as it is not directly connected to a specific provision schedule.

5.2.3 Technical solutions for SOs

The "Technical solutions for SOs" category include the main solutions implemented by the OneNet demos to improve coordination between system operators and more accurately identify the network needs. This category mainly addresses barriers related to the limited coordination for procurement of flexibility by DSO and TSO (B8) and the lack of established methodology for network representation for the distribution grid (B10).

There were four main solutions implemented by the demos, these being: (1) Aligning information flows for data exchange; (2) Accurate forecasting solutions; (3) Bid optimisation and multiple product procurement; and (4) Common models. A generic description of these "macro" solutions can be found in Table 5-16, Table 5-17, Table 5-18 and Table 5-19, along with a more concrete description with examples from the demos, and identification of main similarities and differences on the implemented solutions.

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Table 5-16: Generic description of the "macro" solution on aligning information flows for data exchange

(1) Aligning information flows for data exchange		
Generic description	**Barriers addressed**	**Demos**
Define and test the processes for information and data exchange by and between SOs in the different market stages, from prequalification to procurement. Cross-border data exchange flows are also included to enable FSPs participation across different systems	B2a – Insufficient coordination of different system services over different timeframes for pre-qualification B2b - Insufficient coordination of different system services over different timeframes for planning and forecasting (baselining) B2c – Insufficient coordination of different system services over different timeframes for procurement B2d – Insufficient coordination of different system services over different B7 - Limited cross-border coordination/ integration B8 – Limited coordination for procurement of flexibility by DSO and TSO B9a – Lack of alignment in pre-qualification process B9b – Lack of alignment in planning and forecasting (baselining) process	Greek, Portuguese

This "macro" solution is horizontal to several market stages as is focused on data exchange by and between SOs. This aspect is thoroughly covered within the Portuguese demo that aligns and tests DSO and TSO information flows for prequalification, flexibility needs, maintenance plans, generation and load forecasts and short-circuit forecasts. The data exchange is done through direct communication via APIs between the DSO Data Exchange Platform (DDEP) and the TSO Data Exchange Platform (TDEP), through pre-agreed schemas and formats to guarantee effective communication and interoperability between both platforms. Specific time windows for data exchange were defined and, more specifically for the exchange of data related to flexibility needs, these time windows were aligned with the gate closure times of existing markets, so that the needs are determined after the market closure. The Greek demo foresees the exchange of data related to availability bids for the different market timeframes. This is done through the coordination module of the F-channel platform that enhances interaction between the TSO and DSO, where also requirements are communicated to the SOs and connected FSPs.

The Portuguese demo also addresses cross-border data exchange through the use of OneNet connector for exchange between the DSO, the TSO and the foreign system operator for prequalification purposes, allowing an FSP that is connected to one system (either distribution or transmission level) to be prequalified across-borders.

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Table 5-17: Generic description of the "macro" solution on accurate forecasting solutions

(2) Accurate forecasting solutions		
Generic description	**Barriers addressed**	**Demos**
Improved forecasting solutions to accurately determine flexibility needs by the SOs	B2b – Insufficient coordination of different system services over different timeframes for planning and forecasting (baselining) B9b – Lack of alignment in planning and forecasting (baselining) process B12 – No appropriate baseline methodology and process established for new flexibility markets and new types of flexibility providers (e.g., low voltage flexibility) B17 – Unavailability of adequate information allowing FSPs to anticipate the value of their participation and hence not being able to quantify their business case	Greek, Portuguese

This "macro" solution is strongly connected to the Greek demo through the forecasting module from its F-Channel, which is a tool designed and implemented to be used by SOs. This forecasting module is capable of providing both short-term and long-term forecasts for weather and flexibility volumes, and of interacting with existing markets on a near real-time basis to forward availability bids.

The Portuguese demo also addresses this solution by improving and increasing the frequency of data exchange between the TSO and DSO, through the daily exchange of data related to generation and consumption forecasts by the DSO to the TSO so that these can be taken into account for determining daily flexibility needs by both parties to prevent congestion in both transmission and distribution grids. DSO and TSO specific tools are also developed and/or upgraded for the daily forecast of these needs.

Table 5-18: Generic description of the "macro" solution on bid optimisation and multiple product procurement

(3) Bid optimisation and multiple product procurement		
Generic description	**Barriers addressed**	**Demos**
Joint TSO-DSO procurement of flexibility products through a bid optimisation tool	B2d – Insufficient coordination of different system services over different timeframes for activation B8 – Limited coordination for procurement of flexibility by DSO and TSO	Northern, Polish, Cypriot

Examples of this "macro" solution can be seen in both Northern and Cypriot demos. The Northern demo foresees joint TSO-DSO procurement organised by its TSO-DSO coordination platform (TDCP) which is the central point for bid optimisation that matches flexibility bids and purchase offers in the most economical way, taking into account not only each bid's price, but also its impact on each network component. SOs can submit flexibility needs (energy products) in the platform and can also create calls for tenders (capacity products), which are visible to relevant SOs.

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This solution is also addressed by the Polish and Cypriot demos. The first uses network data for the technical optimal selection of balancing offers taking into account previously accepted offers by the DSO, whereas the second developed an algorithm for activation of multiple products that envisages grid cost minimisation, thus, selecting a combination of products that will lead to reduced grid costs.

Table 5-19: Generic description of the "macro" solution on common models

(4) Common models		
Generic description	**Barriers addressed**	**Demos**
Define a common network representation model covering main network characteristics	B10 - Lack of established methodology for network representation for the distribution grid	Northern, Hungarian, Polish

The definition of a common network model is foreseen in the Northern, Hungarian and Polish demos, the latter resorting to an existing standard KDM model used in Poland by both DSOs and TSOs for their HV networks. The Northern demo has agreed on a common representation of the network, that discloses the topology (nodes and connections), network limits, network forecasted baseflows and PTDF matrix, whereas the Hungarian demo opted for the conversion of DSOs network representation, not only to a common format but an open-source one.

5.2.4 Market access

The "Market access" category includes the main solutions implemented by the OneNet demos to improve market access and promote increased participation by different FSPs in flexibility markets. This category mainly addresses barriers related to the lack of alignment in the prequalification process (B9A), the existence of a uniform access and registration process/platform for assets willing to participate to flexibility markets (B13) and the unavailability of adequate information allowing FSPs to anticipate the value of their participation and hence not being able to quantify their business case (B17).

There were three main solutions implemented by the demos, these being: (1) Flexibility register; (2) Traffic light scheme; and (3) Uniform User Interfaces. A generic description of these "macro" solutions can be found in Table 5-20, Table 5-21, Table 5-22, along with a more concrete description with examples from the demos, and identification of the main similarities and differences in the implemented solutions.

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Table 5-20: Generic description of the "macro" solution on flexibility register

(1) Flexibility register		
Generic description	**Barriers addressed**	**Demos**
Create a single point of contact for the prequalification process, where the FSPs are registered, where their prequalification is done according to predefined requirements and the activated services and resources are stored	B2A – Insufficient coordination of different system services over different timeframes for pre-qualification B9A – Lack of alignment in the pre-qualification process B9B – Lack of alignment in planning and forecasting (baselining) process B9E – Lack of alignment in the settlement process B12 – No appropriate baseline methodology and process established for new flexibility markets and new types of flexibility providers (e.g., low voltage flexibility) B13 – No uniform access and registration process/platform for assets willing to participate in flexibility markets	Northern, Czech, Greek

Three demos include a type of flexibility register: the Northern, the Czech and the Greek. The Northern demo establishes its flexibility register as the single point for prequalification, prequalifying any product to which resource group characteristics are satisfactory according to predefined requirements. In the Greek demo, the flexibility register is integrated within its F-Channel tool, where the prequalification is done only once upon registration of each FSP, including resources' location and other eligibility criteria. Same registration format for all assets.

The Czech demo opts for a simpler approach, with a database comprising the activated services, including a common procedure for the registration of platform users.

Table 5-21: Generic description of the "macro" solution on traffic light scheme

(2) Traffic light scheme		
Generic description	**Barriers addressed**	**Demos**
Deploy a traffic light scheme that provides information on grid availability through a User Interface, where users can check if they can activate their flexibility	B2B – Insufficient coordination of different system services over different timeframes for planning and forecasting (baselining) B2C – Insufficient coordination of different system services over different timeframes for procurement B8 – Limited coordination for procurement of flexibility by DSO and TSO B9C – Lack of alignment in the activation process B17 – Unavailability of adequate information allowing FSPs to anticipate the value of their participation and hence not being able to quantify their business case	Czech, Hungarian

This "macro" solution on the establishment of a traffic light scheme, is a commonly used instrument for determining network availabilities and is implemented by two OneNet demos: Czech and Hungarian. In the

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Czech demo, the traffic light scheme provides information on grid availability, foreseeing that aggregators inform DSOs on procured/activated services. SOs send information on grid availability to a central place and the information is distributed through a dedicated GUI to all grid users in order to provide them with information about if they can/cannot activate their flexibility. This solution allows FSPs to optimise their portfolio and business case for flexibility provision.

The Hungarian demo uses this scheme to support SOs, namely on the activation and to avoid cross-activations between assets participating in both DSO flexibility and the TSO aFRR market. The Hungarian scheme indicates whether DSO activation is allowed, not allowed or allowed under certain conditions by the TSO.

Table 5-22: Generic description of the "macro" solution on uniform User Interfaces

(3) Uniform User Interfaces		
Generic description	**Barriers addressed**	**Demos**
Establish user interfaces open to all FSPs ensuring their unform access	B9A – Lack of alignment in the pre-qualification process B13 – No uniform access and registration process/platform for assets willing to participate to flexibility markets B17 – Unavailability of adequate information allowing FSPs to anticipate the value of their participation and hence not being able to quantify their business case	Northern, Hungarian, Cypriot, French

This "macro" solution is implemented by several demos to make sure there is uniform access to the flexibility platforms developed and to simplify the user journey. Hungarian, Cypriot and French demos have a flexibility platform available for FSPs where they can submit offers for services to be provided in different markets, the latter deploying a blockchain-based solution for it.

To increase the information to the FSPs, the Northern demo has deployed a User Interface specifically to map flexibility needs and provide an overview of the so-called "why not realized trades".

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6 Conclusion and recommendations for integrated and coordinated markets

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 within and across countries. Based on our analysis, we have identified the missing components needed to build integrated and fully coordinated markets for the procurement of harmonised products. The conclusions and recommendations are presented below per main topic: drivers for integration & coordination, examination of markets, barriers and solutions to integrated and coordinated market.

Drivers for coordination & integration:

Integration and coordination of markets serves various goals such as cost efficiency, maximization of welfare, increased reliability, operational security and stability, ensuring sufficient market liquidity and competition.

The future power system and grid must be able to respond to all the drivers: skewed distribution of generation in-feed across EU member countries, technical scarcities (stabilizing the grid, security of supply, managing congestion), ensuring optimal use of flexibility with increased electrification of end-user demand and addressing issues of partial grid alienation. Coordinated and integrated markets are key to maximising the use of existing infrastructure to enable secure, reliable, and cost-effective development of the future transmission/distribution grid.

The purpose of flexibility coordination and integration is to make sure that the allocative efficiency of flexibility used for different purposes is maximized and at the same time, flexibility trading by one market party does not create negative effects for other market parties.

Examination of markets

We observe that most of EU's regulatory and legislative efforts so far regarding the integration of electricity markets are focussed on cross-border capacity allocation, day-ahead, intra-day and balancing markets, as these segments are the most mature and liquid ones. EU legislation on congestion management markets is still in a nascent stage, majorly focusing on cross-zonal congestions and making general provisions that congestion management should be market-based whenever possible. However, as more flexibility providers emerge, especially at the distribution level, and as both market parties and system operators require more flexibilities to manage volatilities from renewable energy sources, a fit-for-purpose legal and regulatory framework will be needed to cover more markets and products.

One of the most immediate improvements that OneNet cluster countries can consider for the participation of flexibility in balancing markets is harmonizing prequalification requirements for balancing markets as well as

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considering ex-post verification of compliance of assets with technical requirements in correspondence with the upcoming network code on demand response.

We also note that there are various developments ongoing at the European level on electricity market design. The Commission has published first electricity market reform proposal on 14th March 2023. Furthermore, the upcoming network code on demand response is expected to remove barriers to flexibility to a large extent. These initiatives represent an opportunity for all OneNet cluster countries to actively participate and drive the development of network code.

Across OneNet clusters we observed that a) there are no organized markets for CM and VC, but SOs use a combination of technical measures and other arrangements such as central redispatching or use of shunt reactors etc. b) most of the time there is no remuneration for counter actions due to the emergency character of the situation and c) most emerging markets for congestion management and voltage control are not linked or integrated with the existing markets such as wholesale and balancing markets unless central dispatch model is used. Thus, to enhance the efficiency of markets and exploit synergies when TSOs and DSOs procure flexibility, coordination and integration between market processes and functions is essential.

Market integration and coordination in practise shows that market operators for emerging platforms for flexibility are investigating ways to interlink or facilitate the exchange of standardized balancing/wholesale and congestion management products, thereby increasing the number of market parties that effectively compete either by simply increasing the size of the market or by encouraging cross-entry between neighbouring member states. This can unlock new business cases that would not have been possible in a smaller market. Such measures can be adopted by OneNet cluster countries wherever adequate. Other measures will require new or revised designs based on the interactions between network levels, sequencing of markets and products traded. Finally, it is important to implement solutions and methodologies that improve voltage control and congestion management across borders via harmonized product definitions, common set of market rules, by trading closer to real-time delivery across borders, optimal bidding zones configurations where appropriate to better reflect structural congestions.

Barriers and Solutions to integrated & coordinated markets

First of all, the mapping of the different barriers, solutions and demos shows that some identified barriers to integrated and coordinated markets are not explicitly addressed in OneNet. These barriers are exclusivity clauses and non-harmonised contracts, lack of incentives in the regulatory mechanisms and the risk of gaming. On the other hand, some barriers are addressed by a majority of the demos, i.e., the barriers related to efficient market access. The survey indicates that these demos are addressing barriers related to provision of uniform access and registration process/platform for assets, ensuring appropriate baseline methodology and process established for low voltage (LV) flexibility. A number of demos have developed a flexibility register that is capable to solve multiple barriers at the same time.

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Overall, it is acknowledged that creating suitable and harmonised product definitions for non-standardised trading products would facilitate participation of small actors in national and local markets and also further improve cross-border trade, hence contributing to building integrated and coordinated markets. It is also acknowledged that a strong cooperation between TSOs and DSOs can lead to an effective and mutually beneficial results and technical solutions for the various services, ensuring efficient operation.

The solutions mapping itself showed a balanced split between the categories of solutions implemented by the OneNet demonstrators: market processes, technical solutions for SOs and market access, with a slightly increased manifestation for market access solutions. Some regional differences were identified between the category of solutions adopted, namely, technical solutions for SOs are more prominent in the Western and Southern clusters, possibly related to the yet initial stage of development of flexibility markets in these countries. On the other hand, the categories regarding market processes and market access were strongly addressed under the Northern and Eastern demos, also depending on the level of participation of FSPs and final consumers participating directly in the demonstrators, which allow for these areas to be best targeted, especially regarding market access component.

A big variability was identified between the solutions identified for each barrier, with different approaches being implemented throughout the demos. Nonetheless, some more recurrent solutions were identified, namely fitting in the market processes and market access categories, such as the use of harmonised products and baselining methods under the market processes, or the adoption of uniform user interfaces and flexibility registers under the market access category. Despite being recurrent to the demos, these solutions are not fully harmonised, as some specifications are of course dependent from the country of the demo and the demo itself, majorly depending on network topology, digital and infrastructure maturity, level of implementation of flexibility markets, among others. Thus, technical solutions appear to be the most varied among the demos, also portraying the different realities and priorities among the system operators present.

Finally, we can compare the demo solutions with the provisions of the framework guidelines on demand response (FGDR) [4]. The main aim of FGDR and the ensuing harmonised rules regarding demand response is to ensure access to all electricity markets for all resources providers. This aim is one of the key objectives of market integration that were defined in this deliverable, namely 'efficient market access for all FSPs, voltage levels and technologies. Having said this, harmonisation of national features as a part of EU regulatory framework must also be weighed against the potential increase of consumer costs as well as real consumer value at national level. The FGDR's focus is, amongst others, on pre-qualification and set out principles, requirements, and processes to simplify the process as much as possible. Unlocking harmonised or standardised products on national level in a reliable way may require additional and different prequalification requirements per country based on the technical requirements of those markets. Several of the solutions implemented by the demos are designed to simplify the process, e.g., by use of a flexibility register. Another point of focus of the FGDR is baselining and measurement. Also here, we see that a number of solutions are provided by the demos following the FGDR

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principles of technology-neutrality, ease, transparency and accuracy. Finally, another focus of the FGDR is the data exchange in the planning or operation phase. This is especially true when integration of constraints of the distribution network in grid security analysis and the cost-effective utilization of appropriate resources for system services requires the timely retrieval and processing of data across different operating systems. We observe that data exchange related aspects are also addressed by demos. More specifically, some demos are centralising all applications and pre-qualification processes, and are guaranteeing a coordinated access to available resources, an optimal selection and activation of available resources and a joint services management through flexibility registers, coordination platforms, or other solutions. These principles are also put forward by the FGDR. Hence, the demos are, to a certain extent, already developing solutions that are in line with the principles and guidelines proposed in the FGDR.

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Annex A A summary of market design parameters for Ancillary Services

The summary below was captured in the ENTSO-E Ancillary Services Survey 2020 and ACER Market Monitoring Report 2020. The recast Electricity Regulation mandates the balancing energy settlements for balancing products to be based on marginal price (pay-as-cleared). However, the ENTSO-E survey in 2020 indicates pay-as-bid was still the dominant pricing method especially for mFRR and aFRR in various member states (EEMCSurvey). Some of the national balancing markets' major design characteristics may skew wholesale pricing signals, thus raising the cost of providing flexibility.

Table A- 1: Summary of market design parameters for Balancing Markets

Market design features of balancing market	European target model	FCR Parameter away from European target model	MS	aFRR Parameter away from European target model	MS	mFRR Parameter away from European target model	MS
Minimum delivery period	5min (mFRR) 15, 30 or 60min (RR)	NA	NA	NA	NA	Longer than 4 hours	None
						4 hours	None
						120 min (twice a day)	None
						90 min (twice a day)	None
						60 min	PT, ES, NL
Maximum delivery period	15, 30 or 60min (RR)	NA	NA	NA	NA	Longer than 4 hours	SI, FI, SK
						4 hours	AT, DE
						120 min (twice a day)	FR
						90 min (twice a day)	None
						60 min	DK, EE, ES, IT, LT, LV, NO, PT, RO, SE
Minimum capacity for prequalification	<=1MW	x > 10MW	RO	x > 10MW	RO	x > 10MW	CZ, NL
		5MW <x<= 10MW	IT	5MW <x<= 10MW	CZ, HU, IT, NO	5MW <x<= 10MW	FR, HU, IT, NO, RO, SE

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		1MW <x <= 5MW	CZ	1MW <x <= 5MW	FI, SI, SE	1MW <x <= 5MW	DK, FI, SK
Minimum bid size for balancing energy	<=1MW	x > 10MW	None	x > 10MW	None	x > 10MW	None
		5MW <x<= 10MW	None	5MW <x<= 10MW	RO	5MW <x<= 10MW	NO, FR
		1MW <x <= 5MW	None	1MW <x <= 5MW	AT, BG, CZ, SK	1MW <x <= 5MW	BG, CZ, DK, FI, HR, RO, SK
Minimum bid size for balancing capacity	<=1MW	x > 10MW	None	x > 10MW	None	x > 10MW	NL
		5MW <x<= 10MW	None	5MW <x<= 10MW	RO	5MW <x<= 10MW	FR, SE
		1MW <x <= 5MW	BG, CZ, RO	1MW <x <= 5MW	AT, BG, CZ, FI, SK, SE	1MW <x <= 5MW	BG, CZ, DK, FI, HR, RO, SI, SK
Aggregation of load	Allowed/Eligible	Not eligible/Not allowed	BE, CY, CZ, GR, LU, MT, PL, PT (only pilot projects), RO, SE, SK				
Validity period of balancing energy bids	15min	NA	NA	4 hours	AT, DE	4 hours	AT, DE
				1 hour	BG, CZ, ES, HR, HU, IT, PL, SI, SK	1 hour	BG, CZ, DK, EE, ES, FI, HR, HU, IT, LT, LV, NO, PT, RO, SE, SI, SK
				30 min	FR, GR	30 min	FR
Procurement lead time	1 day	LI (100% of balancing capacity was procured year-ahead), SK (97% year-ahead), SI (52% year-ahead and 11% month-ahead), HR (92% year-ahead), CZ (72% year-ahead), HU (88% month-ahead)		LI (100% of balancing capacity was procured year-ahead), SK (97% year-ahead), SI (52% year-ahead and 11% month-ahead), HR (92% year-ahead), CZ (72% year-ahead), HU (88% month-ahead)			
Length of balancing capacity contracts	1 day	1 year or more	ES, SI	1 year or more	HR	1 year or more	HR, LV, LT
		1month or more	BG	1month or more	BG, DK, SI	1month or more	DK, SI
Symmetric balancing capacity products	Asymmetrical	Symmetrical	All countries except GR, IE	Symmetrical	DK, PL, RO	Symmetrical	None

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Settlement rule - balancing energy market	Marginal Pricing	Regulated	FR, IT	Regulated	CZ, DK, FR	Regulated	None
		Pay-as-bid	SE	Pay-as-bid	AT, BE, DE, HR, HU, IT, SI, SK	Pay-as-bid	AT, BE, CZ, DE, FR, HR, HU, IT, SI, SK
		Hybrid	IE	Hybrid	GR	Hybrid	IE
Settlement rule - balancing capacity market	Marginal Pricing	Regulated	PL	Regulated	FR, PL	Regulated	None
		Pay-as-bid	BG, CZ, GR, HU, SE, SI, SK	Pay-as-bid	AT, BE, BG, CZ, DE, DK, FI, GR, HR, HU, NL, SE, SI, SK	Pay-as-bid	AT, BG, CZ, DE, GR, HR, HU, LT, NL, SE, SI, SK
		Hybrid	None	Hybrid	None	Hybrid	None
Activation rule	Merit Order	Pro-rata	NA	Pro-rata	BG, CZ, DK, ES, FI, FR, GR, HR, IT, NO, PT, SE	Pro-rata	None
Balancing energy price predetermined in balancing capacity contracts	Not predetermined	Predetermined	IE, SK	Predetermined	SK	Predetermined	IE, SK
Non-contracted balancing energy bids	Allowed	NA	NA	Not allowed	AT, BG, CZ, DK, ES, FI, GR, HR, NO, PL, PT, RO, SE, SK	Not allowed	AT, BG, CZ, EE, PT, RO, SK

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Annex B Summary of consultation moment with demos

As part of Task 3.4, several dedicated moments during the OneNet project duration are scheduled to align the results from WP3 with the results from the demo clusters. These consultation moments would allow the demo clusters to adapt their approach in case deemed useful, or vice versa, to challenge the Task 3.2 recommendations with results from the field.

The joint Task 3.2-Task 3.4 consultation moment was organized in two parts:

- Task 3.2 presents list of theoretical barriers to the demo clusters and asks for input (ex-ante, live and/or ex-post)
- The demo clusters present based on guidance by Task 3.2-Task 3.4

In the first part of the presentation, the following questions were asked to participating audiences representing all demo countries.

- Which OneNet demo cluster are you participating in?
- Which country within the demo cluster do you belong to?
- Can you think of any other barriers related to market integration that are missing from our list?

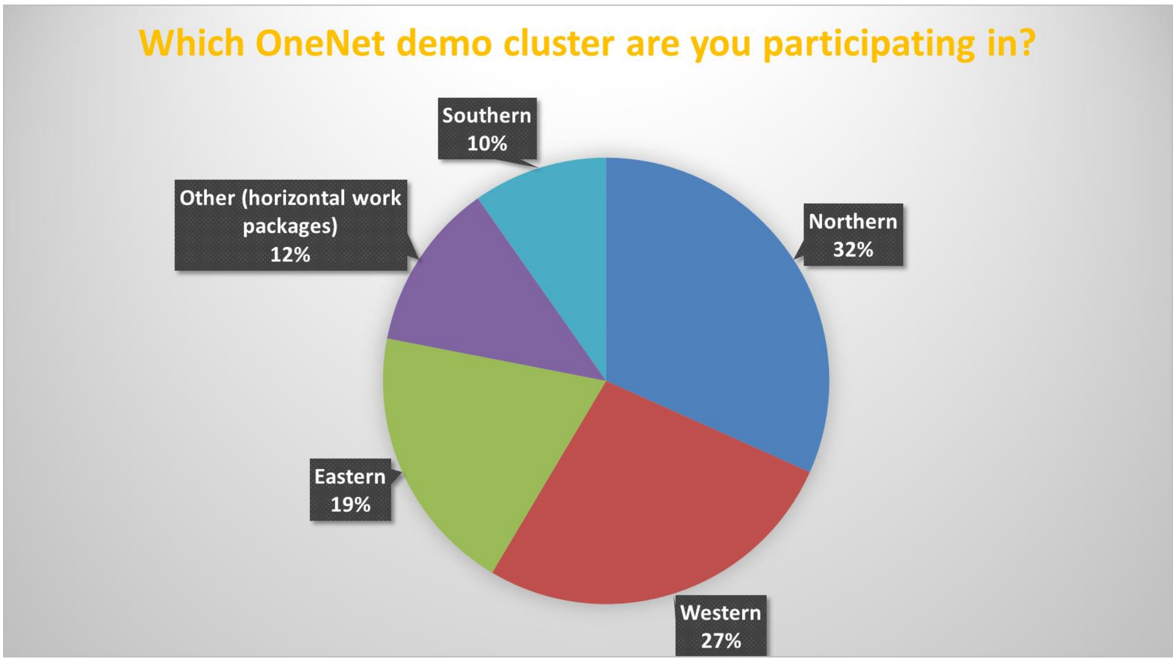

Figure B- 1: Question on demo cluster participation

A total of 35 respondents from various demo clusters participated in the survey.

Figure B- 2: Survey on participation from countries within the clusters

As a part of the first consultation moment with demos, an analysis on the relevance of each of the 21 theoretical barriers for all countries within the demo clusters was conducted. The relevance for each barrier was measured for all countries within the demo cluster on a scale of 0 to 3 with indicators: 'impact' and 'likelihood' into consideration as shown in the simple matrix in Figure B- 3 below. On the horizontal axis 'likelihood' indicates the frequency as well as the probability of the barrier materializing. On the vertical axis 'impact' indicates the severity of the barrier.

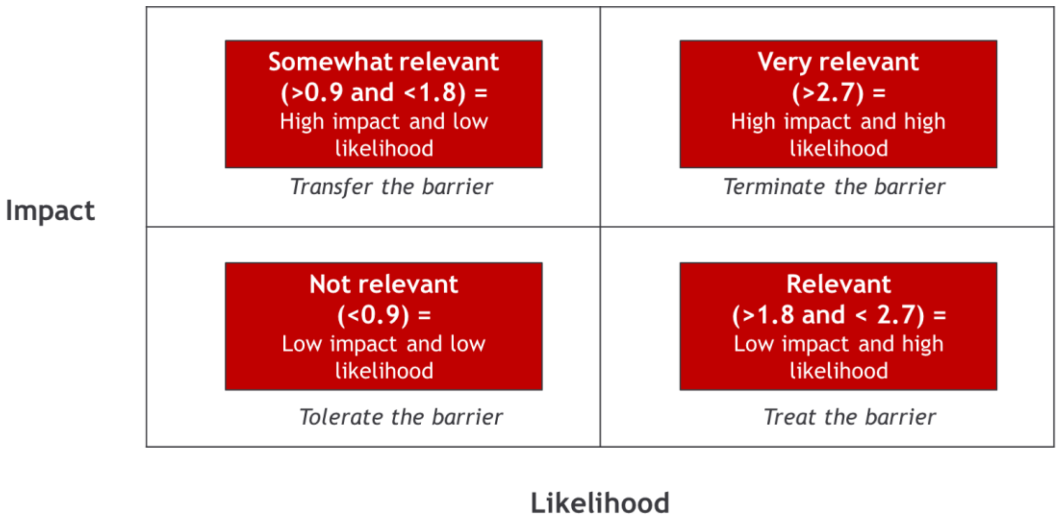

Figure B- 3 Relevance Matrix for barriers

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The relevance of each barrier was scored on a weighted average basis for each of the cluster regions.

- Not relevant: indicates low impact and low likelihood of barrier to occur and thus barrier can be tolerated.
- Somewhat relevant: indicates high impact and low likelihood of barrier to occur and thus the effective management of barrier could be delegated to another party.
- Relevant: indicates low impact and high likelihood of barrier and thus responding party is certain to act on treating the barrier.
- Very relevant: indicates high impact and high likelihood of barrier and thus barrier is going to have significant impact on the business or operation and so it should be terminated.

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Figure B- 4 below outlines relevance of Market coordination related barriers across various clusters.

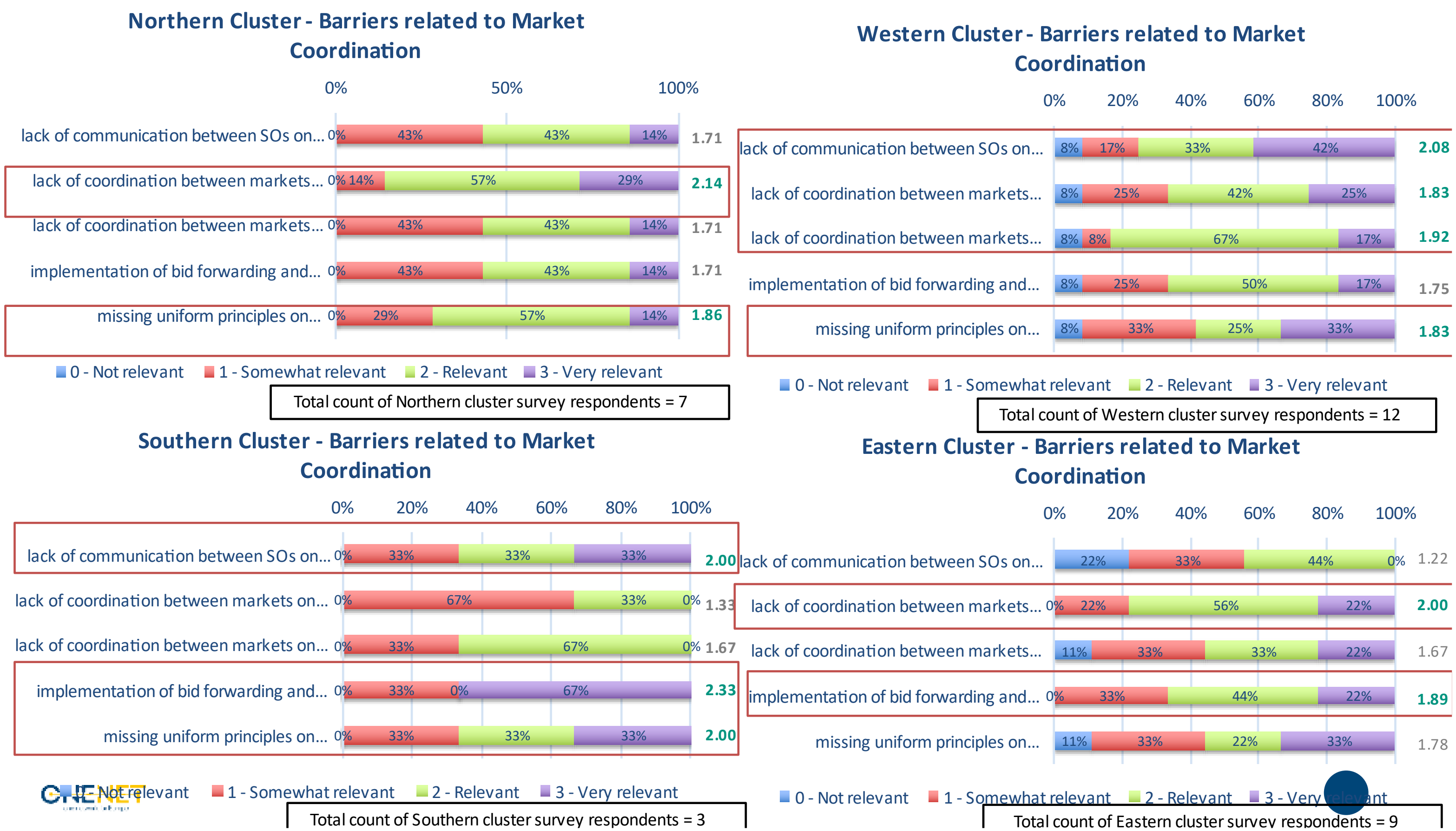

Figure B- 4 Market coordination related barriers across various clusters

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Figure B- 5 below outlines relevance of market architecture and operations related barriers across clusters.

Figure B- 5: Market architecture & operations related barriers across clusters

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And finally, Figure B- 6 below outlines market access and rules for aggregation related barriers across clusters:

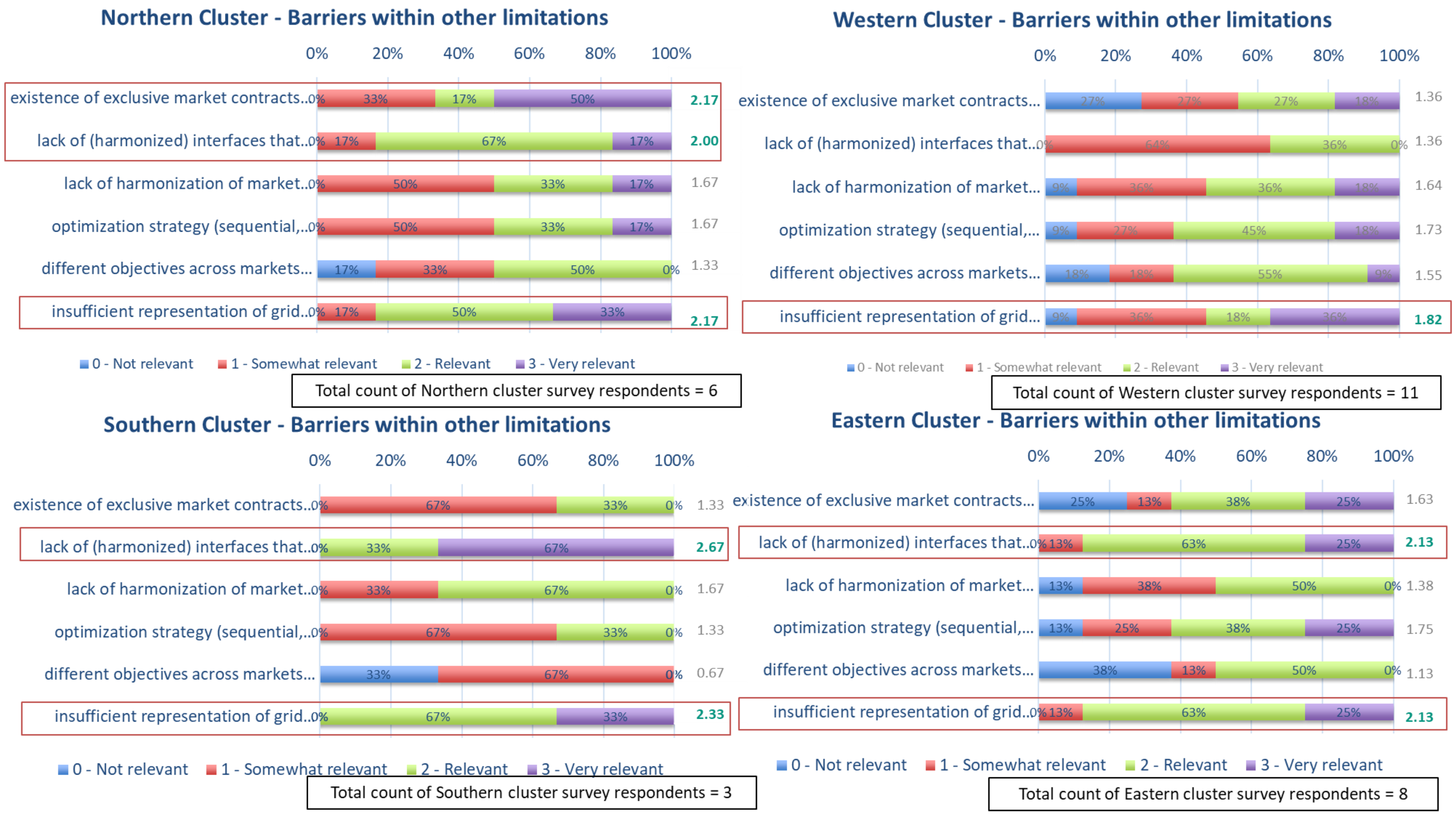

Figure B- 6:Market access and rules for aggregation related barriers across clusters

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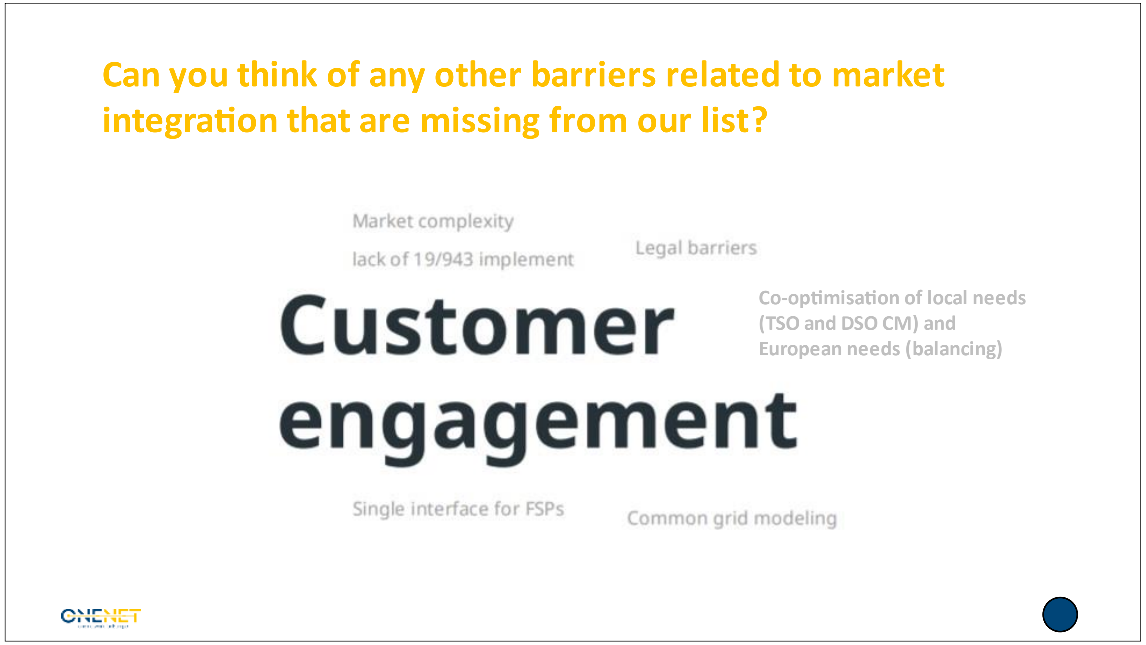

Figure B- 7 Question on missing barriers

The background analysis performed on Survey per cluster is presented in the following figures. A ranking is calculated for each barrier in each cluster by multiplying the relative proportion or percentages by its value in sequence and adding those sums together. For example, as shown in Figure B- 8, in the Northern cluster, a total of six participants respond to survey on lack of harmonization of products. Out of these six participants, 0 (0%) identified this barrier not relevant, 1 (17%) identified this barrier to be somewhat relevant, 2 (33%) identified this barrier to be relevant and 3 (50%) identified this barrier to be very relevant. Finally, a ranking of 2.33 is obtained by multiplying each percentage by value in sequence and combining the values e.g., (0% X 0) + (17% X 1) + (33% X 2) + (50% X 3).

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Northern	lack of communication between SOs on formal allocation of products and resources	lack of coordination between markets on timeframes (especially GOT, GCT and trading resolution of products)	lack of coordination between markets on market phases (from prequalification to settlement)	implementation of bid forwarding and adequate interfaces	missing uniform principles on implementation of interoperable flex resource register	lack of alignment of prequalification processes	lack of harmonization for products	lack of high-level principles of harmonization for market operation (e.g. market clearing type, pricing, procurement frequency ...)	lack of harmonized rules for baselining and settlement	lack of alignment in technical specifications (e.g. of submeters)	different implementations of KORRR data exchange processes and function	ensuring appropriate cybersecurity for operators, market participants and consumers	of procurement areas depending on the service, grid topology and boundaries managed by the involved SO" for market	uncertainty about the role of the market operator	existence of exclusive market contracts that lock flexibility into one market	lack of (harmonized) interfaces that enable market access for FSP value stacking across timescales and different markets	lack of harmonization of market optimization methods between markets (centralized, decentralized, distributed)	optimization strategy (sequential, simultaneous or independent clearing of markets)	different objectives across markets (maximize welfare, minimize costs, or both)	insufficient representation of grid constraints (in the light of more dynamic utilization of the grid)
0 - Not relevant	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
1 - Somewhat relevan	3	1	3	3	2	3	1	0	1	0	2	1	1	2	2	1	3	3	2	1
2 - Relevant	3	4	3	3	4	2	2	2	5	4	4	2	4	4	1	4	2	2	3	3
3 - Very relevant	1	2	1	1	1	1	3	4	0	2	0	3	0	0	3	1	1	1	0	2
Total	7	7	7	7	7	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

	lack of communication between SOs on formal allocation of products and resources	lack of coordination between markets on timeframes (especially GOT, GCT and trading resolution of products)	lack of coordination between markets on market phases (from prequalification to settlement)	implementation of bid forwarding and adequate interfaces	missing uniform principles on implementation of interoperable flex resource register	lack of alignment of prequalification processes	lack of harmonization for products	lack of high-level principles of harmonization for market operation (e.g. market clearing type, pricing, procurement frequency ...)	lack of harmonized rules for baselining and settlement	lack of alignment in technical specifications (e.g. of submeters)	different implementations of KORRR data exchange processes and function	ensuring appropriate cybersecurity for operators, market participants and consumers	of procurement areas depending on the service, grid topology and boundaries managed by the involved SO" for market	uncertainty about the role of the market operator	existence of exclusive market contracts that lock flexibility into one market	lack of (harmonized) interfaces that enable market access for FSP value stacking across timescales and different markets	lack of harmonization of market optimization methods between markets (centralized, decentralized, distributed)	optimization strategy (sequential, simultaneous or independent clearing of markets)	different objectives across markets (maximize welfare, minimize costs, or both)	insufficient representation of grid constraints (in the light of more dynamic utilization of the grid)
0 - Not relevant	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	17%	0%	0%	0%	0%	0%	17%	0%
1 - Somewhat relevan	43%	14%	43%	43%	29%	50%	17%	0%	17%	0%	33%	17%	17%	33%	33%	17%	50%	50%	33%	17%
2 - Relevant	43%	57%	43%	43%	57%	33%	33%	33%	83%	67%	67%	33%	67%	67%	17%	67%	33%	33%	50%	50%
3 - Very relevant	14%	29%	14%	14%	14%	17%	50%	67%	0%	33%	0%	50%	0%	0%	50%	17%	17%	17%	0%	33%
Ranking	1.71	2.14	1.71	1.71	1.86	1.67	2.33	2.67	1.83	2.33	1.67	2.33	1.50	1.67	2.17	2.00	1.67	1.67	1.33	2.17

Figure B- 8: Analysis for Northern Cluster

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Western	lack of communicatio n between SOs on formal allocation of products and resources	lack of coordination between markets on timeframes (especially GOT, GCT and trading resolution of products)	lack of coordination between markets on market phases (from prequalificatio n to settlement)	implementatio n of bid forwarding and adequate interfaces	missing uniform principles on implementatio n of interoperable flex resource register	lack of alignment of prequalificatio n processes	lack of harmonization for products	lack of high-level principles of harmonization for market operation (e.g. market clearing type, pricing, procurement frequency ...)	lack of harmonized rules for baselining and settlement	lack of alignment in technical specifications (e.g. of submeters)
0 - Not relevant	1	1	1	1	1	0	1	1	2	2
1 - Somewhat relevan	2	3	1	3	4	2	4	6	4	3
2 - Relevant	4	5	8	6	3	7	4	1	3	4
3 - Very relevant	5	3	2	2	4	1	1	2	1	1
Total	12	12	12	12	12	10	10	10	10	10

Western	different implementatio ns of KORRR data exchange processes and function	ensuring appropriate cybersecurity for operators, market participants and consumers	of procurement areas depending on the service, grid topology and boundaries managed by the involved SO" for market	uncertainty about the role of the market operator	existence of exclusive market contracts that lock flexibility into one market	lack of (harmonized) interfaces that enable market access for FSP value stacking across timescales and different markets	lack of harmonization of market optimization methods between markets (centralized, decentralized, distributed)	optimization strategy (sequential, simultaneous or independent clearing of markets)	different objectives across markets (maximize welfare, minimize costs, or both)	insufficient representation of grid constraints (in the light of more dynamic utilization of the grid)
0 - Not relevant	0	0	1	1	3	0	1	1	2	1
1 - Somewhat relevan	4	0	3	4	3	7	4	3	2	4
2 - Relevant	5	7	4	3	3	4	4	5	6	2
3 - Very relevant	0	2	1	1	2	0	2	2	1	4
Total	9	9	9	9	11	11	11	11	11	11

	lack of communicatio n between SOs on formal allocation of products and resources	lack of coordination between markets on timeframes (especially GOT, GCT and trading resolution of products)	lack of coordination between markets on market phases (from prequalificatio n to settlement)	implementatio n of bid forwarding and adequate interfaces	missing uniform principles on implementatio n of interoperable flex resource register	lack of alignment of prequalificatio n processes	lack of harmonization for products	lack of high-level principles of harmonization for market operation (e.g. market clearing type, pricing, procurement frequency ...)	lack of harmonized rules for baselining and settlement	lack of alignment in technical specifications (e.g. of submeters)
0 - Not relevant	8%	8%	8%	8%	8%	0%	10%	10%	20%	20%
1 - Somewhat relevan	17%	25%	8%	25%	33%	20%	40%	60%	40%	30%
2 - Relevant	33%	42%	67%	50%	25%	70%	40%	10%	30%	40%
3 - Very relevant	42%	25%	17%	17%	33%	10%	10%	20%	10%	10%
Ranking	2.08	1.83	1.92	1.75	1.83	1.90	1.50	1.40	1.30	1.40

	different implementatio ns of KORRR data exchange processes and function	ensuring appropriate cybersecurity for operators, market participants and consumers	of procurement areas depending on the service, grid topology and boundaries managed by the involved SO" for market	uncertainty about the role of the market operator	existence of exclusive market contracts that lock flexibility into one market	lack of (harmonized) interfaces that enable market access for FSP value stacking across timescales and different markets	lack of harmonization of market optimization methods between markets (centralized, decentralized, distributed)	optimization strategy (sequential, simultaneous or independent clearing of markets)	different objectives across markets (maximize welfare, minimize costs, or both)	insufficient representation of grid constraints (in the light of more dynamic utilization of the grid)
0 - Not relevant	0%	0%	11%	11%	27%	0%	9%	9%	18%	9%
1 - Somewhat relevan	44%	0%	33%	44%	27%	64%	36%	27%	18%	36%
2 - Relevant	56%	78%	44%	33%	27%	36%	36%	45%	55%	18%
3 - Very relevant	0%	22%	11%	11%	18%	0%	18%	18%	9%	36%
Ranking	1.56	2.22	1.56	1.44	1.36	1.36	1.64	1.73	1.55	1.82

Figure B- 9: Analysis for Western Cluster

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Westerr	lack of communication between SOs on formal allocation of products and resources	lack of coordination between markets on timeframes (especially GOT, GCT and trading resolution of products)	lack of coordination between markets on market phases (from prequalification to settlement)	implementation of bid forwarding and adequate interfaces	missing uniform principles on implementation of interoperable flex resource register	lack of alignment of prequalification processes	lack of harmonization for products	lack of high-level principles of harmonization for market operation (e.g. market clearing type, pricing, procurement frequency ...)	lack of harmonized rules for baselining and settlement	lack of alignment in technical specifications (e.g. of submeters)	different implementations of KORRR data exchange processes and function	ensuring appropriate cybersecurity for operators, market participants and consumers	of procurement areas depending on the service, grid topology and boundaries managed by the involved SO" for market	uncertainty about the role of the market operator	existence of exclusive market contracts that lock flexibility into one market	lack of (harmonized) interfaces that enable market access for FSP value stacking across timescales and different markets	lack of harmonization of market optimization methods between markets (centralized, decentralized, distributed)	optimization strategy (sequential, simultaneous or independent clearing of markets)	different objectives across markets (maximize welfare, minimize costs, or both)	insufficient representation of grid constraints (in the light of more dynamic utilization of the grid)
0 - Not relevant	1	1	1	1	1	0	1	1	2	2	0	0	1	1	3	0	1	1	2	1
1 - Somewhat relevan	2	3	1	3	4	2	4	6	4	3	4	0	3	4	3	7	4	3	2	4
2 - Relevant	4	5	8	6	3	7	4	1	3	4	5	7	4	3	3	4	4	5	6	2
3 - Very relevant	5	3	2	2	4	1	1	2	1	1	0	2	1	1	2	0	2	2	1	4
Total	12	12	12	12	12	10	10	10	10	10	9	9	9	9	11	11	11	11	11	11

	lack of communication between SOs on formal allocation of products and resources	lack of coordination between markets on timeframes (especially GOT, GCT and trading resolution of products)	lack of coordination between markets on market phases (from prequalification to settlement)	implementation of bid forwarding and adequate interfaces	missing uniform principles on implementation of interoperable flex resource register	lack of alignment of prequalification processes	lack of harmonization for products	lack of high-level principles of harmonization for market operation (e.g. market clearing type, pricing, procurement frequency ...)	lack of harmonized rules for baselining and settlement	lack of alignment in technical specifications (e.g. of submeters)	different implementations of KORRR data exchange processes and function	ensuring appropriate cybersecurity for operators, market participants and consumers	of procurement areas depending on the service, grid topology and boundaries managed by the involved SO" for market	uncertainty about the role of the market operator	existence of exclusive market contracts that lock flexibility into one market	lack of (harmonized) interfaces that enable market access for FSP value stacking across timescales and different markets	lack of harmonization of market optimization methods between markets (centralized, decentralized, distributed)	optimization strategy (sequential, simultaneous or independent clearing of markets)	different objectives across markets (maximize welfare, minimize costs, or both)	insufficient representation of grid constraints (in the light of more dynamic utilization of the grid)
0 - Not relevant	8%	8%	8%	8%	8%	0%	10%	10%	20%	20%	0%	0%	11%	11%	27%	0%	9%	9%	18%	9%
1 - Somewhat relevan	17%	25%	8%	25%	33%	20%	40%	60%	40%	30%	44%	0%	33%	44%	27%	64%	36%	27%	18%	36%
2 - Relevant	33%	42%	67%	50%	25%	70%	40%	10%	30%	40%	56%	78%	44%	33%	27%	36%	36%	45%	55%	18%
3 - Very relevant	42%	25%	17%	17%	33%	10%	10%	20%	10%	10%	0%	22%	11%	11%	18%	0%	18%	18%	9%	36%
Ranking	2.08	1.83	1.92	1.75	1.83	1.90	1.50	1.40	1.30	1.40	1.56	2.22	1.56	1.44	1.36	1.36	1.64	1.73	1.55	1.82

Figure B- 10: Analysis for Southern Cluster

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Souther	lack of communication between SOs on formal allocation of products and resources	lack of coordination between markets on timeframes (especially GOT, GCT and trading resolution of products)	lack of coordination between markets on market phases (from prequalification to settlement)	implementation of bid forwarding and adequate interfaces	missing uniform principles on implementation of interoperable flex resource register	lack of alignment of prequalification processes	lack of harmonization for products	lack of high-level principles of harmonization for market operation (e.g. market clearing type, pricing, procurement frequency ...)	lack of harmonized rules for baselining and settlement	lack of alignment in technical specifications (e.g. of submeters)	different implementations of KORRR data exchange processes and function	ensuring appropriate cybersecurity for operators, market participants and consumers	of procurement areas depending on the service, grid topology and boundaries managed by the involved SO" for market	uncertainty about the role of the market operator	existence of exclusive market contracts that lock flexibility into one market	lack of (harmonized) interfaces that enable market access for FSP value stacking across timescales and different markets	lack of harmonization of market optimization methods between markets (centralized, decentralized, distributed)	optimization strategy (sequential, simultaneous or independent clearing of markets)	different objectives across markets (maximize welfare, minimize costs, or both)	insufficient representation of grid constraints (in the light of more dynamic utilization of the grid)
0 - Not relevant	0	0	0	0	0	0	0	0	0	1	1	0	3	0	0	0	0	0	1	0
1 - Somewhat relevan	1	2	1	1	1	0	1	2	2	0	0	1	0	1	2	0	1	2	2	0
2 - Relevant	1	1	2	0	1	3	1	1	1	2	1	0	0	2	1	1	2	1	0	2
3 - Very relevant	1	0	0	2	1	0	1	0	0	0	1	2	0	0	0	2	0	0	0	1
Total	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

	lack of communication between SOs on formal allocation of products and resources	lack of coordination between markets on timeframes (especially GOT, GCT and trading resolution of products)	lack of coordination between markets on market phases (from prequalification to settlement)	implementation of bid forwarding and adequate interfaces	missing uniform principles on implementation of interoperable flex resource register	lack of alignment of prequalification processes	lack of harmonization for products	lack of high-level principles of harmonization for market operation (e.g. market clearing type, pricing, procurement frequency ...)	lack of harmonized rules for baselining and settlement	lack of alignment in technical specifications (e.g. of submeters)	different implementations of KORRR data exchange processes and function	ensuring appropriate cybersecurity for operators, market participants and consumers	of procurement areas depending on the service, grid topology and boundaries managed by the involved SO" for market	uncertainty about the role of the market operator	existence of exclusive market contracts that lock flexibility into one market	lack of (harmonized) interfaces that enable market access for FSP value stacking across timescales and different markets	lack of harmonization of market optimization methods between markets (centralized, decentralized, distributed)	optimization strategy (sequential, simultaneous or independent clearing of markets)	different objectives across markets (maximize welfare, minimize costs, or both)	insufficient representation of grid constraints (in the light of more dynamic utilization of the grid)
0 - Not relevant	0%	0%	0%	0%	0%	0%	0%	0%	0%	33%	33%	0%	100%	0%	0%	0%	0%	0%	33%	0%
1 - Somewhat relevan	33%	67%	33%	33%	33%	0%	33%	67%	67%	0%	0%	33%	0%	33%	67%	0%	33%	67%	67%	0%
2 - Relevant	33%	33%	67%	0%	33%	100%	33%	33%	33%	67%	33%	0%	0%	67%	33%	33%	67%	33%	0%	67%
3 - Very relevant	33%	0%	0%	67%	33%	0%	33%	0%	0%	0%	33%	67%	0%	0%	0%	67%	0%	0%	0%	33%
Ranking	2.00	1.33	1.67	2.33	2.00	2.00	2.00	1.33	1.33	1.33	1.67	2.33	0.00	1.67	1.33	2.67	1.67	1.33	0.67	2.33

Figure B- 11: Analysis for Eastern Cluster

Subsequently the dates below were scheduled for the second part of the consultation moment.

- 9 December 2021 at 13h00 CET (1h - 1h30): Northern & Eastern Cluster: Estonia, Finland, Latvia, Czech Republic, Poland, Hungary, Slovenia
- 10 December 2021 at 13h00 CET (1h – 1h30): Western & Southern Cluster: Portugal, Spain, France, Cyprus, Greece

The objective of second part of consultation moment was to obtain answers on the following:

- What is the current approach used in your country when addressing congestion management and voltage control?

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- What are the barriers to the integration of potential congestion management and voltage control markets into the sequence of the current energy markets (wholesale and balancing);
- Which one of these barriers have you identified in the development of the work you are undertaking for your OneNet demo and how you are planning to overtake them? For context, please clarify whether:
    - a DSO participates into congestion management market; and
    - demand facilities and aggregators will participate.
- Do you plan to test potential congestion management and voltage control via market-based process?

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Annex C Template of the questionnaire for demos

Disclaimer

Dear OneNet partner,

In the context of OneNet Task 3.2.2, the objective of this questionnaire is to identify solutions for barriers to coordinated and integrated markets from the perspective of the demonstration activities. More information on Task 3.2.2 and the barriers can be found in the background document.

To achieve this result, this questionnaire asks you, for each barrier that we have identified:

- if you consider this barrier to be relevant for your demo
- if you are tackling this specific barrier in your demo
- in case the barrier is tackled in your demo, to explain the solution.

The last question asks you to list any barriers we might have missed that you consider important or are tackling in your demo.

Please note that some barriers may seem similar but they are linked to different objectives. Hence, depending on the coordination/integration they are linked to, different solutions may exist.

This template intends to contribute to Task 3.2.2 by collecting the Demo perspective.

Thanks for your cooperation.

Nomenclature

FSP	Flexible Service Provider
DSO	Distribution System Operator
DRFG	ACER Framework Guideline on Demand Response
DoA	Description of Action
GCT	Gate Closure Time
DAM	Day-Ahead Market
mFRR	Manual Frequency Restoration Reserves
CM	Congestion management
LV	Low voltage
CCMD	Consumer-centric market design
VC	Voltage control

Legend for answers:

- Y: Yes
- N: No
- ?: Not defined yet

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<u>Background information</u>

	Background information	
Q. 1	Please provide your Name	
Q. 1	Please provide your Surname	
Q. 2	Please provide your Email address	
Q. 3	Which is your Organisation?	
Q. 4	Which is your Demo Country?	
Q. 5	Which demo run will test the aspects mentioned in this questionnaire?	
Q. 6	Expected date for final result	
Q. 7	What is the objective of the demo?	
Q. 8	Are you going to implement a demonstration involving market functioning? If yes, please describe the demonstrated market functioning. If no, please motivate why.	

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Barriers[21]

No.	Barrier	Is the barrier relevant for your demo?	Are you tackling the barrier in your demo?	What is the demo's solution for tackling the barrier?
B1	Insufficient coordination of flexibility markets for system services with energy markets with regard to **timing**.	[Y/N]	[Y/N]	
B2a	Insufficient coordination of different system/flexibility services **over different timeframes for pre-qualification**	[Y/N]	[Y/N]	
B2b	Insufficient coordination of different system/flexibility services **over different timeframes for planning and forecasting (baselining)**	[Y/N]	[Y/N]	
B2c	Insufficient coordination of different system/flexibility services **over different timeframes for procurement**	[Y/N]	[Y/N]	
B2d	Insufficient coordination of different system/flexibility services **over different timeframes for activation**	[Y/N]	[Y/N]	

[21] Definitions for the market phases

Market phase	**Description**
Technical pre-qualification	Set of procedures that allows to check the technical capability of the FSP to provide the system service of interest.
Plan & forecast (Baselining)	Set of procedures that allows to define the baseline for the behaviour of the FSPs expected prior to the service provision. Baselining defines the ex-ante scenario for each FSP.
Procurement	It represents the phase that contains all the procedures in which the need (willingness to acquire – the buyer party) meets the offer (willingness to provide – the seller party). In this phase is defined the binding agreement for the product exchange related to the service of interest between acquirer and the provider.
Activation	It represents the process that triggers the service delivery.
Monitoring	It represents the process that allows to observe (i.e. track) the behaviour of the FSP and/or the grid during the service provision.
Settlement	It entails all the procedures that allow to define and execute the monetary exchange between the buyer and the seller based on the measurement phase of the service provision.

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No.	Barrier	Is the barrier relevant for your demo?	Are you tackling the barrier in your demo?	What is the demo's solution for tackling the barrier?
B2e	Insufficient coordination of different system/flexibility services **over different timeframes for monitoring**	[Y/N]	[Y/N]	
B2f	Insufficient coordination of different system/flexibility services **over different timeframes for settlement**	[Y/N]	[Y/N]	
B3	Lack of harmonization of flexibility products **for system services for both TSO and DSO**	[Y/N]	[Y/N]	
B3	**Additional question**: According to you, where exactly should standardisation/harmonisation take place (among TSOs and DSOs within a country, between countries, …)?			
B4	Exclusivity clauses and non-harmonised contracts	[Y/N]	[Y/N]	
B5	Coordination of explicit procurement of flexibility (flexibility markets) with implicit procurement of flexibility (tariffs, connection agreements,…)	As this barrier is out of scope for T3.2.2, it is not part of the questionnaire		
B6	No specific incentives in the regulatory mechanism (remuneration) that support a common approach between SOs for flexibility procurement**, i.e.,** no common agreed rules on priority use/exclusivity of flexibility for system operators**.**	[Y/N]	[Y/N]	
B7	Limited cross-border coordination/integration	[Y/N]	[Y/N]	
B7	**Additional question**: According to you, are there still remaining barriers/limiting factors that hinder the realisation/operational efficiency of PICASSO, MARI, TERRE, …			

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No.	Barrier	Is the barrier relevant for your demo?	Are you tackling the barrier in your demo?	What is the demo's solution for tackling the barrier?
B8	No process for joint procurement of system services	[Y/N]	[Y/N]	
B9a	Lack of alignment **in pre-qualification process**	[Y/N]	[Y/N]	
B9b	Lack of alignment **in planning and forecasting (baselining) process**	[Y/N]	[Y/N]	
B9c	Lack of alignment **in procurement process**	[Y/N]	[Y/N]	
B9d	Lack of alignment **in activation process**	[Y/N]	[Y/N]	
B9e	Lack of alignment **in monitoring process**	[Y/N]	[Y/N]	
B9f	Lack of alignment **in settlement process**	[Y/N]	[Y/N]	
B10	Lack of established methodology for network representation for the distribution grid	[Y/N]	[Y/N]	
	Additional question: Which methodology is used in the demo to represent the distribution grid (if relevant)?			
	Additional question: Do you consider it a barrier if the methodology differs between regions/countries/…?			
B11	ICT challenges: Large uncoordinated collection of data, timely exchange of (confidential) network information, etc.	As this barrier is out of scope for T3.2.2, it is not part of the questionnaire		
B12	No appropriate baseline methodology and process established for low voltage flexibility	[Y/N]	[Y/N]	
B13	No uniform access and registration process/platform for assets willing to participate to flexibility markets.	[Y/N]	[Y/N]	

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No.	Barrier	Is the barrier relevant for your demo?	Are you tackling the barrier in your demo?	What is the demo's solution for tackling the barrier?
B14	Risk of gaming due to increased information flows and non-harmonised products and processes	[Y/N]	[Y/N]	
B15	Risk of market power due to increased information flows and non-harmonised products and processes	[Y/N]	[Y/N]	
B16	Timings of markets of different carriers are not aligned	As these barriers are out of scope for T3.2.2, they are not part of the questionnaire		
B17	Lack of coordination across energy systems (electricity, gas, heat)			
B18	Quantification of the benefits of sector integration is missing			
B19	Unavailability of adequate information allowing FSPs to anticipate the value of their participation and hence not being able to quantify their business case (also in terms of prices, and anticipated revenues)	[Y/N]	[Y/N]	
B20	Unclear business case for flexibility, especially for low voltage	[Y/N]	[Y/N]	

<u>Open Question</u>

Are there any barriers you are targeting in your demo but not have been mentioned here? If yes, please list them as well as the solution you have developed to remove the barrier. Add rows as per need.	
Barrier	**Solution**

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Annex D Template of the questionnaire for T3.2 partners

Disclaimer

Dear OneNet partner,

In the context of OneNet Task 3.2.2, the objective of this questionnaire is to identify solutions for barriers to coordinated and integrated markets from the perspective of the T3.2 partners. More information on Task 3.2.2 and the barriers can be found in the background document.

To achieve this result, this questionnaire asks you, for each barrier that we have identified:

- if you consider this barrier to be relevant
- to provide an example of this barrier (general example of from your country)
- to propose a solution to remove the barrier

The last question asks you to list any barriers we might have missed that you consider important.

Please note that some barrier may seem similar but they are linked to different objectives. Hence, depending on the coordination/integration they are linked to, different solutions may exist.

This template intends to contribute to Task 3.2.2 by collecting the point of view of the T3.2 partners.

Thanks for your cooperation.

Nomenclature

FSP	Flexible Service Provider
DSO	Distribution System Operator
DRFG	ACER Framework Guideline on Demand Response
DoA	Description of Action
GCT	Gate Closure Time
DAM	Day-Ahead Market
mFRR	Manual Frequency Restoration Reserves
CM	Congestion management
LV	Low voltage
CCMD	Consumer-centric market design
VC	Voltage control

Legend for answers:

- Y: Yes
- N: No
- ?: Not defined yet

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957739

Background information

	Background information	
Q. 1	Please provide your Name	
Q. 9	Please provide your Surname	
Q. 10	Please provide your Email address	
Q. 11	Which is your Organisation?	

Barriers[22]

[22] Definitions for the market phases

Market phase	**Description**
Technical pre-qualification	Set of procedures that allows to check the technical capability of the FSP to provide the system service of interest.
Plan & forecast (Baselining)	Set of procedures that allows to define the baseline for the behaviour of the FSPs expected prior to the service provision. Baselining defines the ex-ante scenario for each FSP.
Procurement	It represents the phase that contains all the procedures in which the need (willingness to acquire – the buyer party) meets the offer (willingness to provide – the seller party). In this phase is defined the binding agreement for the product exchange related to the service of interest between acquirer and the provider.
Activation	It represents the process that triggers the service delivery.
Monitoring	It represents the process that allows to observe (i.e. track) the behaviour of the FSP and/or the grid during the service provision.
Settlement	It entails all the procedures that allow to define and execute the monetary exchange between the buyer and the seller based on the measurement phase of the service provision.

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No.	Barrier	Do you consider this barrier as relevant?	Please provide an example of the barrier	Please provide a solution for removing the barrier
B1	Insufficient coordination of flexibility markets for system services with energy markets with regard to **timing**.	[Y/N]		
B2a	Insufficient coordination of different system/flexibility services over different timeframes for pre-qualification	[Y/N]		
B2b	Insufficient coordination of different system/flexibility services over different timeframes for planning and forecasting (baselining)	[Y/N]		
B2c	Insufficient coordination of different system/flexibility services over different timeframes for procurement	[Y/N]		
B2d	Insufficient coordination of different system/flexibility services over different timeframes for activation	[Y/N]		
B2e	Insufficient coordination of different system/flexibility services over different timeframes for monitoring	[Y/N]		
B2f	Insufficient coordination of different system/flexibility services over different timeframes for settlement	[Y/N]		
B3	Lack of harmonization of flexibility products for system services for both TSO and DSO	[Y/N]		
	Additional question: According to you, where exactly should standardisation/harmonisation take place			

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No.	Barrier	Do you consider this barrier as relevant?	Please provide an example of the barrier	Please provide a solution for removing the barrier
	(among TSOs and DSOs within a country, between countries, …)?			
B4	Exclusivity clauses and non-harmonised contracts	[Y/N]		
B5	Coordination of explicit procurement of flexibility (flexibility markets) with implicit procurement of flexibility (tariffs, connection agreements,…)	As this barrier is out of scope for T3.2.2, it is not part of the questionnaire		
B6	No specific incentives in the regulatory mechanism (remuneration) that support a common approach between SOs for flexibility procurement, i.e., no common agreed rules on priority use/exclusivity of flexibility for system operators.	[Y/N]		
B7	Limited cross-border coordination/integration	[Y/N]		
	Additional question: According to you, are there still remaining barriers/limiting factors that hinder the realisation/operational efficiency of PICASSO, MARI, TERRE, …			
B8	No process for joint procurement of system services	[Y/N]		
B9a	Lack of alignment in pre-qualification process	[Y/N]		
B9b	Lack of alignment in planning and forecasting (baselining) process	[Y/N]		
B9c	Lack of alignment in procurement process	[Y/N]		

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No.	Barrier	Do you consider this barrier as relevant?	Please provide an example of the barrier	Please provide a solution for removing the barrier
B9d	Lack of alignment in activation process	[Y/N]		
B9e	Lack of alignment in monitoring process	[Y/N]		
B9f	Lack of alignment in settlement process	[Y/N]		
B10	Lack of established methodology for network representation for the distribution grid	[Y/N]		
	Additional question: Which methodology is used in the demo to represent the distribution grid (if relevant)?			
	Additional question: Do you consider it a barrier if the methodology differs between regions/countries/…?			
B11	ICT challenges: Large uncoordinated collection of data, timely exchange of (confidential) network information, etc.	As this barrier is out of scope for T3.2.2, it is not part of the questionnaire		
B12	No appropriate baseline methodology and process established for low voltage flexibility	[Y/N]		
B13	No uniform access and registration process/platform for assets willing to participate to flexibility markets.	[Y/N]		
B14	Risk of gaming due to increased information flows and non-harmonised products and processes	[Y/N]		

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No.	Barrier	Do you consider this barrier as relevant?	Please provide an example of the barrier	Please provide a solution for removing the barrier
B15	Risk of market power due to increased information flows and non-harmonised products and processes	[Y/N]		
B16	Timings of markets of different carriers are not aligned	As these barriers are out of scope for T3.2.2, they are not part of the questionnaire		
B17	Lack of coordination across energy systems (electricity, gas, heat)			
B18	Quantification of the benefits of sector integration is missing			
B19	Unavailability of adequate information allowing FSPs to anticipate the value of their participation and hence not being able to quantify their business case (also in terms of prices, and anticipated revenues)	[Y/N]		
B20	Unclear business case for flexibility, especially for low voltage	[Y/N]		

Open Question

Are there any barriers you are targeting in your demo but not have been mentioned here? If yes, please list them as well as the solution you have developed to remove the barrier. Add rows as per need.	
Barrier	**Solution**

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