Techno-economic assessment of proposed market schemes for standardized products

D11.2

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Approved by Project Coordinator	Padraic McKeever, 22/12/2023

Dissemination Level	Public

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

Issue Record

Planned delivery date	31/12/2023
Actual date of delivery	22/12/2023
Status and version	Final, version 1

Version	Date	Author(s)	Notes
0.1	2023-07-05	Matteo Troncia	Template customised for T11.2
0.2	2023-12-04	All authors	Document submitted for review
0.3	2023-12-05	Matteo Troncia	Executive summary and updated conclusions
0.4	2023-12-13	Formal reviewers	Document revision received
0.5	2023-12-13	Matteo Troncia	Partial document update
0.6	2023-12-18	All authors	Document submitted for quality check
1.0	2023-12-21	All authors	Final document version

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 optimises 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 centralised to a highly decentralised system, grid operators have to adapt to this changing environment and adjust their current business model to accommodate faster reactions and adaptive flexibility. This is an unprecedented challenge requiring an unprecedented solution. The project brings together a consortium of over 70 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 standardised 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 organised 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
ACER	Agency for the Cooperation of Energy Regulators
AE	Availability and Activation
ANN	Artificial Neural Networks
ASM	Active System Management
BA	Balancing Market
BESS	Battery Energy Storage System
BRIDGE	EU initiative Smart energy systems research and innovation
BRP	Balance Responsible Party
BSP	Balancing Service Provider
BUC	Business Use Case
CACM	Guideline on capacity allocation and congestion management
CEP	Clean Energy Package
CM	Congestion Management
CNN	Convolutional Neural Networks
CZE	Czech Republic
DA	Day Ahead
DER	Distributed Energy Resources
DR	Demand Response
DSO	Distribution System Operator
DSR	Demand Side Response
EAM	activation Energy Market
EBGL	Electricity Balancing Guideline
EC	European Commission
EDSO	European Distribution System Operators association
ENTSO	European Network of Transmission System Operators
ESP	Spain
EU	European Union
EUDSO	European DSO Association
EUR	Euro
EV	Electric Vehicle
FAT	Full Activation Time
FCR	Frequency Containment Reserve
FGDR	Framework Guideline for Demand Response
FRR	Frequency Restoration Reserve

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FSR	Frequency Stability Reserve
GCT	Gate Closure Time
GOT	Gate Opening Time
GRC	Greece
HUN	Hungary
HV	High Voltage
ICT	Information and Communication Technology
ID	Intraday
IDM	Intraday Market
IMO	Independent Market Operator
INEA	Innovation and Networks Executive Agency
IT	Information Technology
LG	Local Granularity
LSTM	Long Short-Term Memory
LV	Low Voltage
MO	Market Operator
MT	Medium-term
MTU	Market Time Unit
MV	Medium Voltage
MVA	Mega Volt Ampere
MW	Megawatt
NA	Not Applicable
NCDR	Network Code on Demand Response
NEMO	Nominated Electricity Market Operator
NOC	Northern Cluster
NRA	National Regulatory Authority
NRT	Near Real Time
POL	Poland
PQ	Active and reactive power
PRT	Portugal
PTDF	Power Transfer Distribution Factor
PV	Photovoltaic
RES	Renewable Energy Sources
RR	Reactive Reserve
RT	Real Time
SCADA	Supervisory Control and Data Acquisition
SP	Service Provider
ST	Short-Term

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TD	Transmission and distribution
TMF	Theoretical Market Framework
TSO	Transmission System Operator
US	United States
VC	Voltage Control
WA	Week-ahead
WP	Work Package

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Executive Summary

The OneNet project's Task 11.2, "Techno-economic assessment of proposed market schemes for standardised products," evaluates the market designs and products adopted by OneNet demonstrators from technical, economic, and regulatory standpoints. This task involves an in-depth analysis of product and market harmonisation within European electricity markets.

The product harmonisation assessment involves four steps: mapping demonstrators against OneNet products, identifying barriers to product harmonisation, and formulating harmonisation recommendations. Barriers identified include technical, economic, regulatory, and social challenges. The assessment recognises technical, economic, regulatory, and social barriers:

- Technical Barriers: Challenges arise due to unique grid requirements or specific market area structures and technologies, potentially limiting harmonisation. ICT challenges also pose significant barriers to harmonisation.
- Economic Barriers: The varying stages of product life cycles, with some products being well-established and others emerging, create discrepancies in harmonisation efforts.
- Regulatory Barriers: National grid codes or regulations may impose limitations or may not yet include necessary specifications for harmonisation.
- Social Barriers: Historical differences in national systems and stakeholder practices, known as path dependency, can impede harmonisation efforts.

The product harmonisation assessment concludes that harmonisation adds value when there is alignment in service needs, geographical characteristics, and market operational processes. Essential for harmonisation are similarities in grid structure, market maturity of System Operators (SOs), interoperable ICT systems for data exchange, and a sufficiently liquid and competitive market.

The market architecture harmonisation assessment focuses on improving resource allocation efficiency and value stacking for market participants. The methodology involves describing the market architecture, scrutinising market design features related to bid forwarding, and identifying barriers to these processes. The analysis covers:

- Permitting aggregation in all markets.
- Advocating for free bidding in balancing energy markets.
- Designing local market timings to align with existing wholesale markets.
- Enhancing synergies between local flexibility and intraday markets.
- Policy recommendations focus on improving procurement efficiency and providing revenue stacking potential for market players.

The harmonisation assessment for market phases aims to establish common procedures among markets to reduce redundancies. The harmonisation assessment has been addressed considering prequalification, baselining, and market clearing:

- Prequalification: Recommends adaptable regulatory frameworks and more efficient processes closer to the trading phase. Harmonised prequalification should account for scalability to fit various market structures.
- Baselining: Suggests a flexibility register operator for prequalification actions and improved baseline calculations using submeters. Additional research is needed for innovative baseline methods suitable for evolving flexibility provision paradigms.
- Market Clearing: Identifies a preference for pay-as-bid solutions in new local system service markets due to limited competition and operational concerns. Recommendations include simplification, transparency, and openness in market clearing processes to increase SPs' revenue streams and reduce activation prices.

The analysis underlines the critical need for a harmonised approach to market design for an efficient and integrated European electricity market. The detailed findings and recommendations serve as a vital guide for future developments towards a more interconnected and effective market system, emphasising the importance of aligning technical, economic, and regulatory frameworks across different European markets for successful harmonisation. This harmonised approach is pivotal for the transition to a more efficient, integrated European electricity market, fostering better resource allocation and value creation for all market participants.

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1 Introduction

1.1 Task 11.2

The OneNet project aims to develop and demonstrate harmonised market architectures to enhance value stacking, increase market participation, and unlock the potential of available resources. Market harmonisation is critical to preventing market fragmentation, enabling customer participation, and simplifying the decision-making process for investors. These objectives are achievable through the promotion of harmonisation across products, services, and market models, underpinned by interoperable platforms [1]. Furthermore, market harmonisation is crucial to enhance value stacking, increase market participation, and unlock the potential of the available resources. These objectives can be achieved fostering harmonisation across products, services, and market models supported by interoperable platforms.

Within the scope of the OneNet project, Task 11.2 is dedicated to tackling the intricacies of formulating a harmonised market design framework and evaluating the harmonisation potential of the OneNet demonstrators. This document presents a concise overview of the background for the methodological framework employed for analysing the OneNet demonstrators' solutions. It also introduces original methodologies designed for assessing the harmonisation potential of the solutions implemented by the OneNet demonstrators. In addition, the document delves into a detailed discussion of the assessment outcomes, focusing on evaluating the harmonisation potential across various dimensions including products, market architecture, and market phases. Conclusively, based on the insights gained from the harmonisation assessment, this document discusses the challenges encountered in harmonisation and offers recommendations and lessons learned. These insights are instrumental in contributing to the development of integrated electricity markets.

Task 11.2 addresses the challenges related to defining a harmonised market design. Specifically, among the drivers identified in Task 11.2, it has been acknowledged that markets can efficiently cooperate by utilising the same pool of resources only if they are harmonised. The conditions characterising harmonised markets are product compatibility and market design compatibility. The former requires a harmonised product design, while the latter concerns the harmonisation of the architectural market features and of the market phases.

Market architecture refers to the overall structure and design of the market, consisting of dimensions such as participants, market timings, bidding conditions etc. Harmonisation of market architecture can be considered as standardisation of market features along certain dimensions. Instead of setting a unique value as in the standardisation process, harmonisation limits the possible values to a range, such that variations within markets are not completely eliminated. Harmonising markets between different European countries have increased the cross-border trades, enhanced system reliability and enabled market integration [2]. In the context of local markets, within a country or a region, harmonisation of local markets could bring similar benefits. However,

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harmonising the local market architecture across Europe is a different question as the probability of local market in one country interacting with the local market of another country is very rare (say local markets in Norway interacting with another one in Portugal). Furthermore, the benefit of harmonisation is not only about direct interaction of the marketplaces, but also about clarity and simplicity for the same stakeholders (e.g. SPs, MOs) to enter all those different markets. Additionally, the long-term goal for the development of the local markets is to integrate the local market players to the wholesale markets, such that the whole system can be run at a cost-efficient manner. Considering these aspects, in this task, we analyse the harmonisation potential between local markets and the existing wholesale markets in a country.

One of the harmonisation goals is to develop a set of products which address the need for common system services exploiting all network resources. Common products can be defined as harmonised products with a reduced variation, either only in their attributes, or in attributes as well as in attribute values. The products that the local markets trade such as congestion management are also used at the national and cross-border market levels. Clearly, due to the difference in the voltage levels, there might be some design elements that should be different between the two markets (e.g. locational granularity, system operator). However, if the other design elements are harmonised between the local and the wholesale markets, the coordination between the markets could be increased. One way of coordinating these markets is forwarding uncleared bids from the local markets to the wholesale markets trading a similar product, or to clear bids simultaneously for various markets.

Furthermore, the electricity market represents a complex framework characterised by different layers and elements that mutually interact. The SOs' acquisition of system services from third parties can be addressed by different mechanisms (i.e. flexible access and connection agreements, dynamic network tariffs, flexibility market, bilateral contracts, cost-based mechanism, obligation) [3], [4]. Generally, mechanisms for acquiring system services are formed by several phases [5], [6]. The integration of acquisition mechanisms with harmonised market phases enhances the overall efficiency of the electricity market since reduces redundant procedures [7]. For example, the implementation of a shared flexibility register between mechanisms encourages interconnectivity and market liquidity. Additionally, coordinating a settlement phase among flexibility mechanisms diminishes the amount of transactions. Both instances lead to enhancing the economic effectiveness of the global market structure.

1.2 Objectives of the Work Reported in this Deliverable

Task 11.2, entitled "Techno-economic assessment of proposed market schemes for standardised products", analyses the proposed market schemes from different perspectives: technical, economic and regulatory. T11.2 relies on the activities and outcomes of various OneNet tasks. As a part of Work Package (WP) 11 “From OneNet demonstrators to EU wide implementation of coordinated market schemes and interoperable platforms for standardised system products” contributes to the overall objective to analyse the results of the different cluster demonstrations to extract conclusions for EU implementation, including the corresponding supportive policies

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to enable TSOs-DSOs-customers to procure harmonised system products in a coordinated manner through interoperable platforms. In particular, the T11.2 objectives are:

- Evaluation of the technical, economic and regulatory aspects for harmonised products
- Assessment of the feasibility implementation of market schemes and their impact on the existing markets
- Identify the challenges for the implementation of standardised products and market schemes in the EU.

Specifically, among the possible harmonising strategies, it is assumed in T11.2 that markets can efficiently cooperate by utilising the same pool of resources only if they are harmonised; the conditions characterising harmonised markets are product compatibility and market design compatibility. The former requires a harmonised product design, while the latter concerns the harmonisation of the architectural market features and of the market phases.

In T11.2 activities, product harmonisation assessment entails comparing the OneNet harmonised products, their attributes and values to the products being used by the demonstrators (now and expected in the future), and the define barriers to product harmonisation from the viewpoint of these demonstrators.

In T11.2 activities, market harmonisation is analysed considering two perspectives:

- Market architecture: the framework and features that outline various components of the overall market, including submarkets, products, actors, and so forth.
- Market phases: the sequential stages within market processes, encompassing stages like prequalification, bidding, and clearing.

Hence, this document, describing the T11.2 activities, has the following objectives:

- Provide the necessary elements of the theoretical and regulatory background concerning market harmonisation in EU.
- Present the original methodology formalised for assessing the harmonisation potential of the OneNet demonstrators' market-based solutions.
- Describe the activities addressed for assessing the harmonisation potential and barriers of the OneNet demonstrators' solutions concerning products, market architecture, and market phases.
- Analyse the barriers and challenges to achieving market harmonisation and propose effective solutions to overcome them.
- Provide recommendation and best practices to support harmonised market design among the EU countries.

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1.3 Outline of the Deliverable

This report is organised as follows:

Section 2 describes the methodologies formalised for the harmonisation assessment of the OneNet demonstrators' solutions dealing with harmonised products, market architecture, and market phases.

Chapter 3 provides the analysis of the necessary elements from the theoretical and regulatory landscape concerning the harmonisation of products, market architectures, and market phases.

Chapter 4 describes the activities addressed for the product harmonisation assessment of the OneNet solutions and provides general recommendations for product harmonisation based on the OneNet experience.

Chapter 5 outlines the market architecture harmonisation assessment activities for OneNet solutions and offers significant policy recommendations derived from the bid forwarding analysis based on OneNet's expertise.

Chapter 6 describes the harmonisation assessment of the OneNet demonstrators, covering the market phases of pre-qualification, baselining and market clearing. Furthermore, a risk assessment is conducted to provide recommendations for developing harmonised market phases.

Chapter 7 concludes this document by presenting the primary findings and formalising recommendations and lessons learnt based on the analyses addressed.

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1.4 How to Read this Document

The primary connections between Task 11.2 and other tasks and Work Packages (WPs) within the OneNet project are illustrated in Figure 1.1.

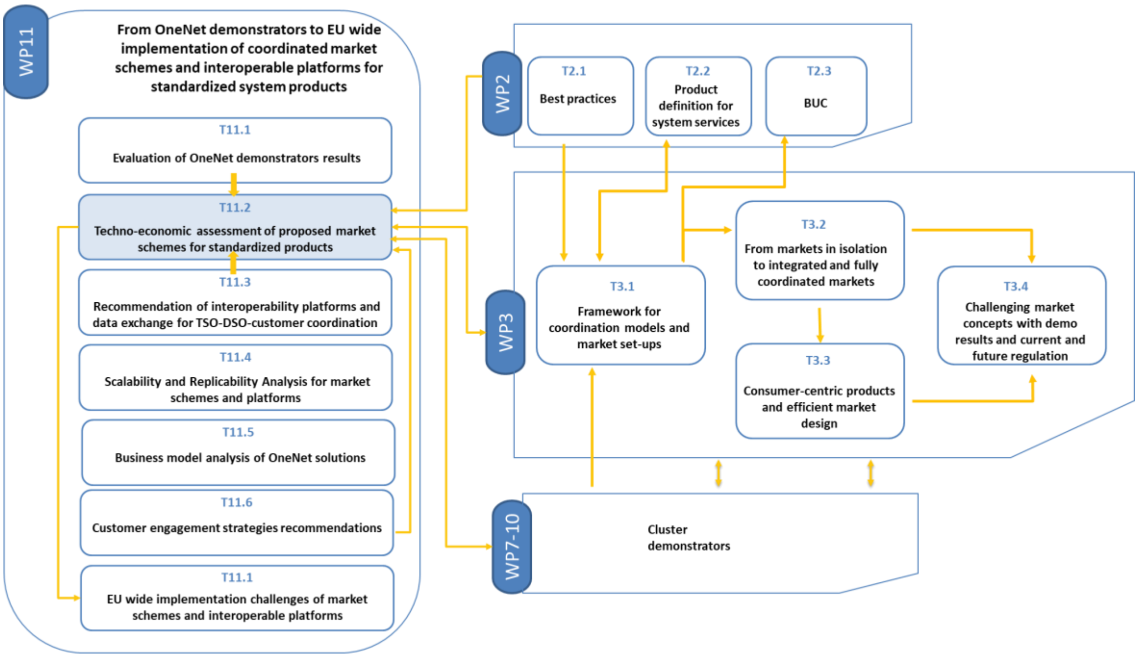

Figure 1.1: Relationship among OneNet Task 11.2 and other tasks and WPs in the OneNet project

The technical parameters of the standardised products and business use cases (defined in WP2) are compared between the demonstrators, and it is identified to what extent some of the parameters can be harmonised at EU level or whether some local products are needed to meet regional, national or local needs. Similarly, the market schemes (defined in WP3) are analysed to identify possible gaps or missing links, such as market or regulatory barriers to implementation, based on the experience of the demonstrators. A qualitative assessment (i.e. based on data availability and the service under consideration) is carried out to evaluate the different alternatives for harmonised products and market schemes, including the feasibility of the proposed IT solution. This assessment, addressed in T11.2, considers consumer involvement and compliance with the consumer-centric approach. In addition, the assessment provides risk analysis for the proposed model by including aspects related to behavioural strategies, gamming, market power risks and economic efficiency criteria. Where possible, network and market data from the demonstrators is used for such assessment. The techno-economic assessment considers different processes for the provision of system services, including pre-qualification, procurement, activation and billing. In addition, cross-cutting requirements between these processes, such as cyber security and legacy systems (defined in WP5) or data management requirements (defined in WP6) are considered where relevant. The results of Task 11.2 are obtained in close cooperation with

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demonstration clusters to reflect the actual market entry in each country, to promote scalability and to avoid high-level results that are not directly applicable.

Task 3.1 analysed the lessons learnt from the projects studied in Task 2.1 in terms of coordination models and market designs, together with feedback from operational flexibility market concepts (e.g. NODES, Enera, GOPACS, PICLO). Based on this input, a theoretical framework has been formalised to describe and define high-level coordination models and more specific market design concepts using commonly accepted market terms and dimensions. The proposed framework provides a common basis and terminology in the OneNet project between the specific work packages to categorise the market concepts studied in the project and tested in the demonstrators, and to facilitate communication on the concepts both internally and externally. Task 3.1 also mapped the structure of the market design concepts in the OneNet clusters with the Theoretical Market Framework (TMF), which describes the market concepts of the OneNet project in a consistent way.

Task 11.2 also draws on the results of Task 2.2 in WP2, which defined the relevant product attributes for a set of standardised system services. In Task 2.2, the different services and products proposed in the different research and innovation activities (Task 2.1) and the models defined in the Active System Management (ASM) report [8] are processed to contribute to the elaboration of a theoretical framework of product attributes leading to a set of standardised products for OneNet, addressing the need for common system services using all network resources. The various services and products demonstrated in the OneNet clusters are mapped to this theoretical framework.

Based on the results of Task 3.1 and the input from the OneNet demo clusters, Task 3.2 conducted a gap analysis of the steps required to move from isolated markets (e.g. for a specific SO, 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 SPs, within and across countries. Task 3.2 evaluated the adequacy of the market concepts proposed in the previous task for the procurement of the standard products identified in WP2 (Task 2.2) and identified the missing components needed to build integrated and fully coordinated markets. The main aspects of integration examined are 1) integration of existing and future services; 2) cross-border integration; 3) integration of different services over different time horizons; 4) joint procurement of services by TSOs and DSOs from the same asset pool; 5) integration with energy markets (DA, ID); 6) integration of flexibility procured through markets with other flexibility solutions such as dynamic connection agreements, dynamic network tariffs; 7) Inclusion of locational information and network conditions in market clearing; 8) Application and standardised categorisation of baseline methodologies to be used for the procurement of single and combined products; 8) Proposal of efficient settlement rules between service providers, retailers and balance responsible parties. The results of the gap analysis of existing market concepts are used in T11.2 as input to propose and design fully integrated, future-proof market concepts for network services. The impact on the role of system operators are assessed for the different concepts proposed.

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Considering that the proposed products and integrated market designs should be efficient, transparent, non-discriminatory and technologically neutral, and that new market design aspects could lead to the introduction of market distortions, including market power or gaming risks, Task 3.3 analysed in more detail the potential market distortions that could arise in the proposed integrated market designs that could have an impact on the efficient functioning of the market. Task 3.3 analysed in more detail the potential market distortions that could arise in the proposed integrated market designs, which could have a negative impact on the efficient functioning of the market. Dynamic market simulations are used to illustrate the impact of potential market inefficiencies on the market outcome of the proposed integrated market designs. Task 3.3 captures the interconnection between aggregators, suppliers and consumers and overcomes various participation issues such as risk aversion, uncertainty, lack of trust, lack of liquidity and valuation of inconvenience (considering the consumer perspective), including ensuring an adequate level of market surveillance. In addition, possible market distortions and inefficiencies (e.g. due to strategic behaviour of market participants) are examined and specific measures to overcome them are proposed. The resulting set of recommendations on how to fine-tune the proposed products and integrated market designs to remove potential market inefficiencies and distortions are considered as an input to Task 11.2.

Task 11.2 is dependent on Task 3.4's activities to seamlessly incorporate the market design concepts established in Task 3.2 with the outcomes from Task 3.3 and the results obtained from the demo clusters. Additionally, Task 3.4 scrutinised and recognised the pertinent (EU and national) regulatory factors that may affect the suggested integrated market design. However, D3.4 did not build general recommendations regarding baselining, prequalification and local market operation targeted at the EU level. This is indeed where D3.4 and D11.2 complement each other, with D11.2 aiming to go step further in the recommendations on the market phases. This analysis is exploited picking from the conclusions gathered within D3.4 but complementing it with learnings from the demonstrators results and further analyses made in T11.2. Moreover, Task 11.2 involves the examination of market design provisions in significant EU legislation (CEP, Network Codes, etc.) through the T3.4 findings that have been transferred.

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2 Methodological approaches for market design harmonisation assessment

2.1 Methodology for product harmonisation assessment

The goal of the product harmonisation assessment is to compare the attributes and attribute values of the standardised OneNet products against the demonstrators' product attributes and values and identify to which extent some of the attributes and their values can be harmonised at the EU level or whether some local products are required to meet regional, national or local needs.

The methodology for this assessment consisted of four steps. Figure 2.1 provides a graphical overview of these different steps.

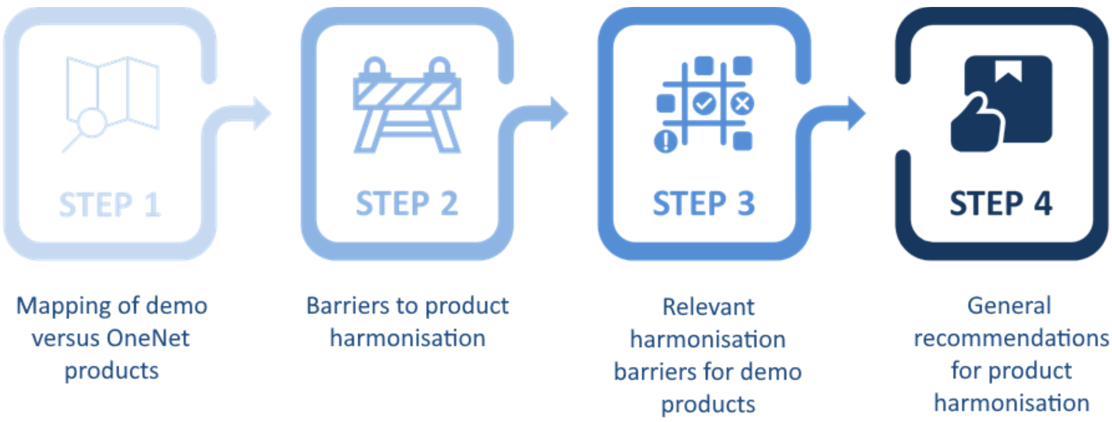

Figure 2.1: Overview of product harmonisation assessment methodology

In a first step, an overview was compiled of the demo products and their attributes and values. This information was then mapped against the standardised/harmonised OneNet products that were defined in Task 2.2 [9]. For each of the demo product attributes and values a check was conducted to which extent they aligned with or diverged from the OneNet harmonised product attributes and values. To better understand the reasons behind the demonstrators' choices, they were asked to provide the rationale for their choices. These results were then presented during an internal WP3-WP11 workshop in November 2022.

In a second step, a list of product harmonisation barriers was compiled. This list was based on work done in [9] and complemented with relevant literature from [17][18][19]. This overview was then presented during an internal WP3-WP11 workshop for feedback from the OneNet partners in March 2023.

In a third step, the reasons why demonstrators did not comply with the OneNet products, attributes and their values were looked into. This was done by means of a survey where the demonstrators were also asked

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whether they would continue to use their demo products in real-life implementation, the reasons behind these decisions and if they expected any product harmonisation barriers (compiled in step 2) to apply to them in the foreseeable future.

In a fourth and final step, based on the demo feedback and relevant literature, a list of general recommendations for product harmonisation was developed.

2.2 Methodology for market architecture harmonisation assessment

As mentioned in section 1.1, market harmonisation is crucial for avoiding fragmentation, facilitating customer engagement, and simplifying decision-making for investors. The OneNet project aims to develop harmonised market architectures to enhance value stacking, increase participation, and unlock potential resources. Task 11.2 outlines a methodology emphasising the importance of harmonisation in efficiently cooperating markets, focusing on product and market design compatibility. In this section, a methodology for market architecture harmonisation assessment in presented. This methodology relies on the concept of efficient allocation of resources across markets, since avoiding bottlenecks in the acquisition of system services allows in principle to increase the efficiency of the overall market functioning. The methodology for market architecture harmonisation assessment aims identifying the conditions for markets to efficiently co-operate in using the same pool of resources for system service provision. Bid forwarding is considered as the mean to coordinate markets to allocate resources and creating value for market participants [13], [14]. A schematic representation of the bid forwarding process is given in Figure 2.2.

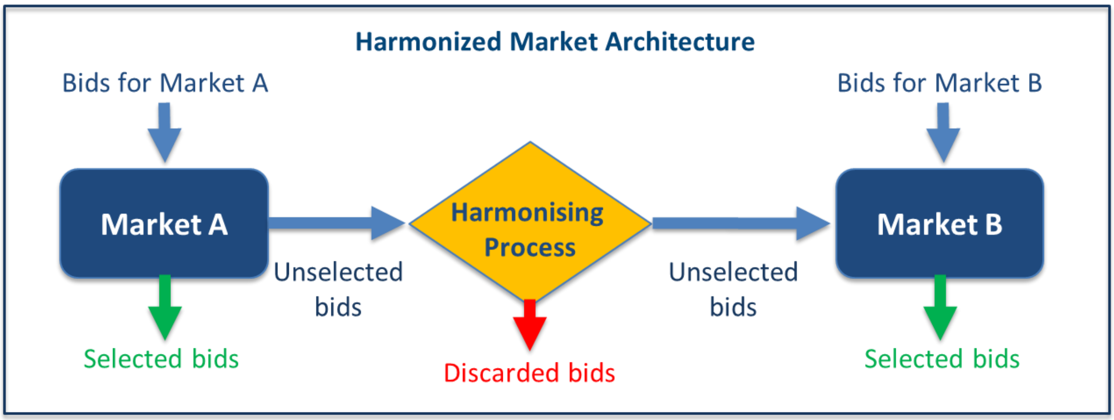

Figure 2.2: Simplified representation of bid forwarding process, adapted from [13]

In a multi-market setup like the European electricity markets, the bids that are not cleared in one market could be used in another market trading a similar product. This process of forwarding unused eligible bids from one market to another is called bid forwarding [13]. In most cases, an intermediate bid processing stage is used to select and process bids for use in the second market (for instance, if the minimum bid size allowed in the second market is higher than the one in the first market, an aggregation stage might be needed before

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forwarding the bids to the second market). The bid forwarding process depicted in Figure 2.2 can occur for example between sequential markets or from a local to a central market, and vice-versa.

The framework guidelines of demand response (FGDR) recognise bid forwarding as a way to connect local markets with the existing wholesale markets [15]. This process is enabled by a responsible market agent, either the market operator or the system operator, depending on the national terms and conditions. Additionally, the permissible bid manipulations within the bid processing stage should also be clearly defined in the national terms and conditions, as these activities should be fair and non-discriminatory and should not financially benefit the bid forwarding responsible agent. A detailed discussion of these factors is presented in [13], [14].

2.2.1 Methodology for bid forwarding capability assessment

Harmonising markets deal with the definition of the conditions allowing the exploitation of the same pool of resources. Therefore, identifying the barriers to market harmonisation passes through recognising the market design features that require uniformity. Bid forwarding between markets can be considered a mean for coordination since it allows reallocating resources between them by leveraging value stacking for market participants. Bid forwarding between markets requires some degree of harmonisation among them; hence a set of design features have to comply with certain conditions. Under certain circumstances, a harmonising process is necessary to meet harmonisation requirements to enable bid forwarding.

To assess the bid forwarding potential between markets, we employ a three-step approach [13], [14], depicted in Figure 2.3:

- Step 1: Describing the market architecture and pinpointing the submarkets of interest.
- Step 2: Scrutinising the market design features relevant to bid forwarding and identifying barriers.
- Step 3: Formulating recommendations to overcome the identified barriers.

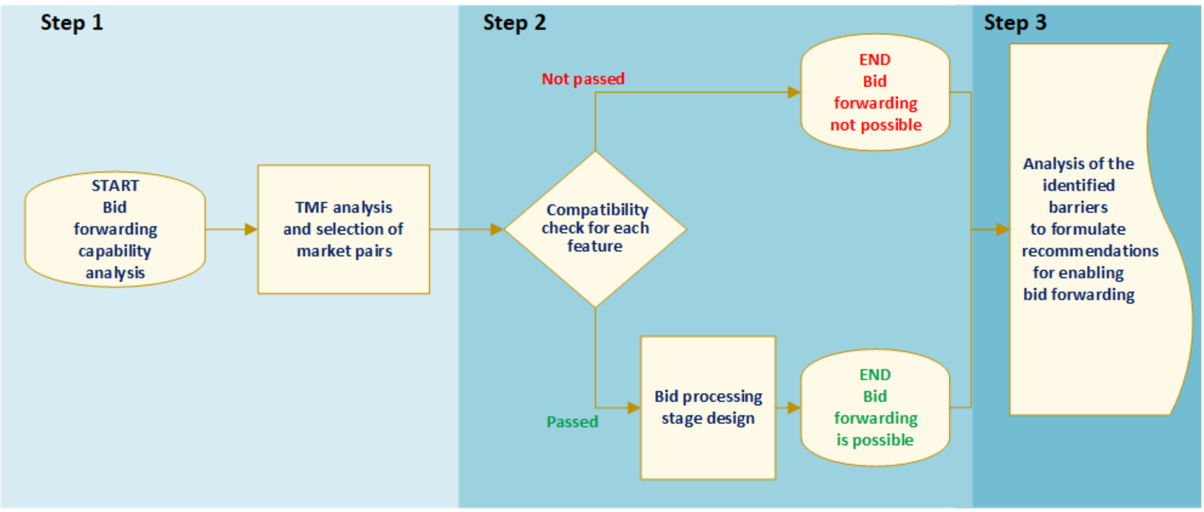

Figure 2.3: Methodology adopted for bid forwarding analysis

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The evaluation of market harmonisation necessitates a thorough depiction of the market architecture along with its corresponding design features. To achieve this, a systematic market design and analysis tool, the Theoretical Market Framework (TMF) [16], is leveraged. Developed within the OneNet project to assist demonstrators in market design, the TMF proves invaluable in capturing all essential information for the analysis of bid forwarding potential and barriers. Employing a set of market design pillars and features, the TMF enables a comprehensive description of the market architecture. Therefore, in the initial step of the adopted methodology (i), TMF is employed to identify and describe the markets under consideration for the harmonisation assessment. A detailed description of TMF can be found in Chapter 5.

The second step of the adopted methodology (ii) analyses the market design features impacting bid forwarding between the market couples identified in the first step. The considered market design features are defined in Table 2.1:. Considering bid forwarding enabling conditions, two types of market design features can be defined. A market design feature is considered necessary (N) if it requires that both markets strictly comply with it. A market design feature is considered conditional (C) if it does not require strict compliance of the two markets; hence it admits a harmonising processing stage as a "market connector" that converts the leftover bids of the first markets to make them compliant with the second market requirements. In this second step of the methodology, the analysis addressed is twofold; it allows to check bid forwarding feasibility and identify the corresponding barriers in the market architecture, if any. Hence, bid forwarding barriers identification is a sub-step of the adopted methodology. With this aim, the markets under analysis are pairwise compared in terms of the design choices defined in Table 2.1:. All conditions in Table 2.1: have to be satisfied for bid forwarding feasibility. Since their typology, the design features of type N should be considered first. For each market design feature, first, whether the two markets adopt the same solution is checked. If it is the case, the bid forwarding condition is satisfied, and it is possible to move to the assessment of the following feature. Otherwise, if the market design feature is of type C, the conditions for defining a market connector are studied by analysing whether some room for compatibility exists between the two markets. In other words, the entry requirements of the second market are evaluated considering the ones of the first market to identify the conditions under which the leftover bids of the first market can be converted and submitted to the second market. In this stage, the barriers to bid forwarding are identified. Conversely, if the design feature is of type N, if the corresponding condition is not satisfied, bid forwarding cannot be enabled by devising a market connector; in this case, only significant changes in the market architecture would enable bid forwarding.

The final step of the adopted methodology concerns the analysis of the identified barriers to formulate recommendations and develop design solutions and market connectors to enable bid forwarding between the studied market couples.

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Table 2.1: Design features for bid forwarding

Design feature	Definition	Type	Required bid processing stage
Gate closure time (GCT)	Instant when submitting or updating bids is no longer permitted [16]	N	No bid forwarding possible
Market time unit (MTU)	Period for which a market price is established [16]. Minimum duration for which a sell or a buy bid can be placed.	C	Splitting divisible products or merging divisible or indivisible products to meet the new MTU conditions
Local granularity (LG)	Level of detail to represent the location of a buying unit or a selling unit [17].	C	Allow addition of locational information and filter only bids that contain it
Technical requirements	Set of technical conditions a product must realise to participate in the market [16].	N	Filter only bids that meet the technical requirements
Type of product	Type of product traded in a market (e.g., capacity or energy)	C	Predefine conditions for capacity-energy bid conversion. Forwarding bids to a market with capacity reservation obligation is not possible
Allowed technology	Type of generation, consumption, or storage units eligible in a market.	C	Filter only allowed technology
Aggregation condition	Conditions to combine multiple resources in a buy or sell offer [9]	C	Regroup or recombine the assets according to the new aggregation conditions
Minimum bid size	Minimum volume (capacity or energy) of the bid in a market [18]	C	Aggregate the bids to reflect minimum bid size and bid granularities
Bid structure	Level of complexity allowed in a bid [19]	C	Filter the bids that meet the bid requirements

2.3 Methodology for market phases harmonisation assessment

As described in section 2.2, the electricity market represents a complex framework characterised by different layers and elements that mutually interact. A market can be considered coordinated if the submarket composing submarkets can co-operate by using the same pool of resources; this cooperation requires a satisfactory level of harmonisation considering the respective market features. Harmonised markets are characterised by a certain level of compatibility considering the three main constitutive elements: products, market architecture, and market phases.

The SOs' acquisition of system services from third parties can be addressed by different mechanisms (i.e. flexible access and connection agreements, dynamic network tariffs, flexibility market, bilateral contracts, cost-based mechanism, obligation) [3], which process requires accomplishing several steps [3], [4]. Generally, mechanisms for acquiring system services are formed by several phases [5], [6], as listed in Table 2.2.

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Table 2.2: Phases for system service acquisition mechanisms process (adapted from [5], [6])

Acquisition Mechanisms Phase
Technical pre-qualification
Baselining
Procurement
Activation
Measurement
Settlement

Technical pre-qualification - Set of procedures that allows checking the SP's technical capability to provide the system service of interest. It comprises grid and product prequalification, SP qualification [5], [6], [15].

Grid prequalification: Process aiming at verifying that the delivery of a service can be technically supported by the connecting grid and any intermediate grids [15].

- **Product prequalification**: Process aiming at verifying the compliance of the asset(s) of the SP to the technical requirements of the service.

SP qualification: Process aiming at verifying the service provider capability to deliver a service having the adequate communication tools or having the SP data correctly registered together with the associated units, among others [15].

Baselining - Set of procedures that allows to define the baseline[1] for the behaviour of the SPs expected prior to the service provision. Baselining defines the ex-ante scenario for each SP [5].

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) [5]. In this phase is defined the binding agreement for the product exchange related to the service of interest between acquirer and the provider. Procurement is formed by several steps:

- **Bid collection**
- **Market clearing**
- **Quantification** of cleared quantities related to bids and **definition** of related remunerations

Activation - It represents the process that triggers the service delivery [5].

Measurement - It represents the process that allows to observe (i.e. track) the behaviour of the SP and/or the grid during the service provision for collecting the measures legally attesting the service provided [5].

[1] 'baseline', as defined in the ACER's Framework Guidelines for Demand response represents "the counterfactual reference about what the SP's BRP allocated volume would be in the absence of the activation for the provision of the respective service" [15].

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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 [5].

The integration of flexibility mechanisms with coordinated market phases significantly enhances overall electricity market efficiency. Therefore, the design of future electricity market architecture should prioritise maximising the coordination of flexibility market phases [7]. For instance, implementing a shared flexibility register among mechanisms promotes interoperability and market liquidity. Additionally, coordinating a settlement phase across flexibility mechanisms reduces the number of transactions. Both examples contribute to the improvement of the economic efficiency of the overall market architecture.

Efforts are required to establish best practices for designing the coordination of market phases, spanning from prequalification to settlement [20]. This necessitates a comprehensive understanding of the distinct stages of the market, their intersections, and the potential synergies therein.

Enhanced overall market efficiency is achieved through commonalities among market phases, products, and services. In a market architecture where more sub-markets adopt shared market phases and procedures, applicability extends across multiple products, services, system operators (SOs), and markets, thereby reducing the need for duplicated procedures. Conversely, establishing dedicated market phases and procedures for each product, service, SO, and sub-market necessitates duplicating procedures to facilitate market participation. However, certain scenarios may require specific processes to accommodate unique characteristics or needs, such as technical requirements or local specificities.

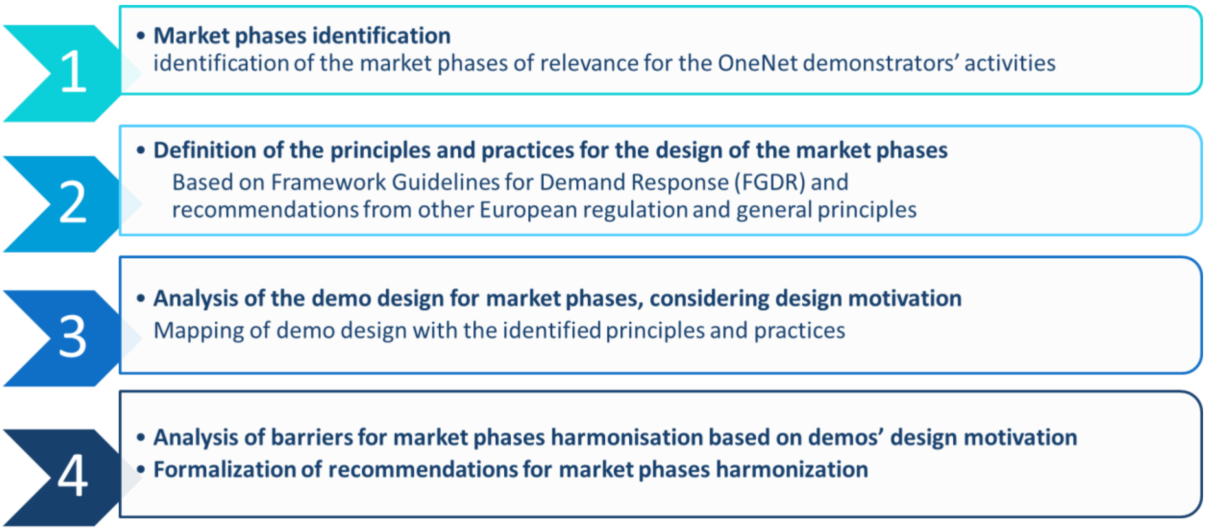

Figure 2.4: Methodology used for the market phases' harmonisation assessment of the OneNet demonstrators' solutions

This document describes the Task 11.2 activities related to the assessment of the demonstrator solutions in terms of market phase harmonisation potential. The aim is to formalise recommendations for market phase harmonisation based on the analysis of the barriers to market phases harmonisation identified by the OneNet demonstrators' experience. The methodology adopted for the Task 11.2 market phase harmonisation potential is described in Figure 2.4.

In the OneNet project, the demonstrators deal with market-based acquisition mechanisms; therefore, the definition and sequence of market phases described in this document are aligned with that context.

Furthermore, the assessment of market phase harmonisation is supplemented by a risk assessment activity aimed at identifying potential risks associated with implementing the demonstrators' solutions and proposing suitable mitigation actions. The adopted methodology for risk assessment is outlined as follows.

The qualitative risk methodology consists of the different steps presented in Figure 2.5. The first step consists of each of the main features of the market phases (baseline, prequalification, and market clearing) specifying the main critical risks related to evaluation criteria to guarantee a good functioning of the mechanism. Once the critical risks were identified, the demonstrators that included such market phases as part of their scope were asked to evaluate the hazard level choosing between: no, low, mid, and high, the associated probability among: no, low, mid, high.

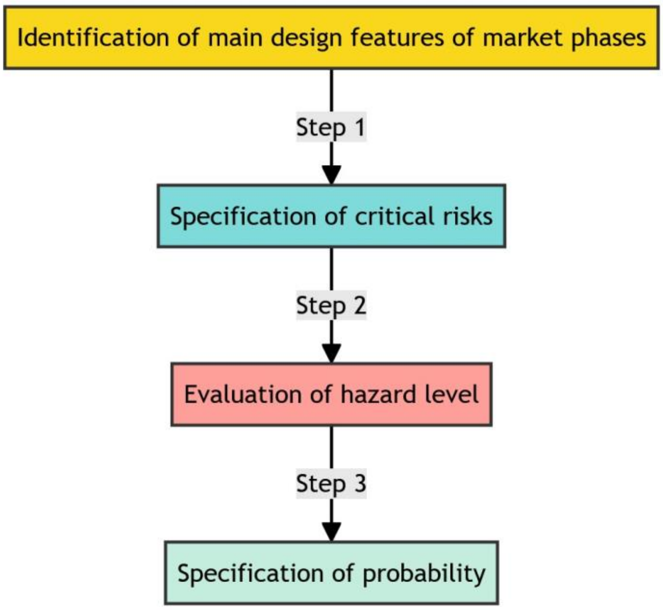

Figure 2.5: Risk analysis methodology

The identification of the critical risk relates to the potential unfulfillment of evaluation criteria which are: economic efficiency, customer participation, reliability and implementation concerns. These criteria can compete with each other to a certain extent. For instance, a specific solution that delivers an efficient outcome may face some implementation challenges as privacy concerns, among others.

Below the evaluation criteria are presented and the unfulfillment of those criteria may represent a performance drawback.

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1. Economic efficiency

Economic efficiency focuses on enhancing social welfare by reducing the total costs borne by the system. This goal includes short-term and long-term system costs, highlighting the importance of optimising resource distribution across different periods.

a. Short-term efficiency

The **short-term efficiency** refers to achieving the lowest costs incurred by producing a service in the short term. These costs are variable and depend on the current quantity level. In the short term, certain costs, like investments, are fixed and do not change with the production level therefore they are not considered when accounting for short-term efficiency.

Short-term efficiency can be reduced in the case of **gaming**, which refers to the exercise of manipulating or exploiting market rules, systems, or conditions to gain an unfair advantage or profit, often at the expense of market integrity and fairness. This can involve strategies like artificially inflating prices, using insider information, or creating misleading market conditions.

Agents that can influence market conditions, such as the price, supply, and the entry of new competitors, can do it to their advantage and potentially to the detriment of consumers and the overall market efficiency. **Market power** conditions can affect both short-term and long-term efficiency.

b. Long-term efficiency

Long-term economic efficiency refers to the optimal allocation of resources in an extended period considering both variable and fixed costs.

Innovation is also related to long-term efficiency as developing new technologies, processes, or products can lead to more efficient use of resources or reduced environmental impact. Innovations are expected to contribute to cost reduction in the long run but may increase short-term costs as investments in innovative solutions are needed. Therefore, there could be a trade-off between short-term and long-term efficiencies.

2. Customer participation: especially for small ones

The inclusion of active participation of small customers in the electricity market is one of the key objectives of recent European regulation. As stated in [21], the Clean Energy Package (CEP) promotes demand response, which is defined as "the change of electricity load by final customers compared to their normal or current consumption patterns in response to market signals, including in response to time-varying electricity prices or incentive payments, or in response to the acceptance of the final customer's offer to sell the reduced or increased demand at a price in an organised market, as defined in Article 2(4) of Commission Implementing Regulation (EU) No. 1348/2014, whether alone or through aggregation" (art. 2) [22]. Consequently, customers are encouraged to adjust their consumption in response to market signals, aligning with short-term variations

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from their usual usage patterns. Furthermore, the updated Electricity Directive requires Member States to support energy management services and ensure the implementation of smart metering systems.

As part of customer participation equity concerns can also be considered as certain customer groups may face higher entry barriers than others due to energy literacy, among other factors. Certain actions focused on these groups can be foreseen.

3. Reliability

Reliability in electricity systems refers to the ability of the power system to provide a continuous supply of electricity to all consumers, under both normal and abnormal conditions, in a stable and safety manner.

When considering SO services, the reliability refers to the provision of services to fulfil the SO needs and according to the specifications.

4. Implementation concerns

Market implementations or changes require modifications of procedures and costs for participants. As part of the developments, the following are some of the critical aspects:

a. Changes from legacy systems

Integrating new systems or processes with existing infrastructure requires careful planning and execution and poses challenges in terms of technical expertise, scalability, and integration with existing systems.

b. Data management requirements

Certain market developments may require large data and exchange among agents. Data need to fulfil different conditions such as accuracy, compliance with the regulatory requirements, privacy, (cyber) security, scalability and flexibility to accommodate new data needs, and interoperability from multiple data sources (e.g. internal and external).

c. Stakeholders' alignment

Implementation of new markets and changes on existing ones requires aligning the interests and concerns of these diverse groups can be challenging.

d. Transparency and simplicity

Transparency and simplicity are key criteria serves as the means to verify the extent to which the other principles and objectives are being fulfilled. By providing detailed information on how different implementations and designs, stakeholders can assess the compliance with established principles and objectives.

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3 Analysis of relevant regulatory frameworks

This section provides the current regulatory context for the three themes this deliverable addresses, namely product harmonisation, market harmonisation and market phases harmonisation.

3.1 Regulatory framework for product harmonisation

Currently, Regulation (EU) 2017/2195 [23] defines standard balancing products (art. 25) and specific balancing products (art. 26) and lists the minimum set of standard characteristics and additional characteristics defining standard products. Article 2(28) defines a 'standard balancing product' as a harmonised balancing product defined by all TSOs for the exchange of balancing services.

No standardisation currently exists for congestion management and voltage control products. Different definitions for congestion management exist in current legislation, such as in art. 2, 17, 18 and 19 of Regulation (EU) 2015/1222 (Guideline on capacity allocation and congestion management - CACM) [24] or art. 2(2)(c) of the Commission Regulation (EU) 714/2009 on conditions for access to the grid for cross-border exchanges in electricity [25].

However, there is currently a process ongoing for the development of a new network code on demand response. To that goal, ACER developed a Framework Guideline on Demand Response (FGDR) [15], based on which efforts started for the writing of the new network code on demand response (NCDR), led by ENTSO-E and the EU DSO Entity. Currently, a draft NCDR exists [26] and stakeholder discussions are ongoing, with the process aimed to be finalised by the first half of 2024. These two documents also focus on product definition and harmonisation for standard and specific balancing products and congestion management and voltage control products. The FGDR set out the framework for the development of the new network code and, with regard to products and product harmonisation, it was stated that:

- The minimum bid granularity should be reduced at least for the first bid of each BSP to not higher than 0.1 MW for all balancing capacity and accordingly for all balancing energy products.
- Requirements for the definitions of products for CM and VC should be provided as well as a process for establishing standardised products at national level in the terms and conditions for local service providers.
- A common European list of attributes should be defined for products used for congestion management and voltage control that shall be used by SOs when describing the products to be procured.

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These provisions were then translated in the draft NCDR in the following manner[2]:

- Art. 29 of the draft NCDR requires a reduction of the bid granularity of standard balancing products at one decimal starting from the minimum bid size, intended to facilitate the participation of smaller resources in balancing services by means of aggregation.
- Nationally standardised products are proposed as part of the national terms and conditions, ensuring transparent consultation and non-discrimination, while also addressing specific needs from SOs.
- Annex 1 of the draft NCDR provides a list of product attributes, which is to be reviewed every two years.
- Congestion management products shall be standardised at national level, using the attributes of the list.

3.2 Regulatory framework for harmonising markets for system services

The effective integration of flexible resources into an electric system necessitates appropriate economic benefits for the services they offer. For smaller-sized resources, participating solely in energy markets may yield minimal revenues, as demonstrated in various studies [27]–[29]. However, SPs with ownership of generation, consumption, and/or storage units have the potential to offer both energy and ancillary services. Therefore, the profitability of SPs relies on diversifying revenue streams through participation in various eligible markets, commonly referred to as revenue-stacking [29].

In European markets, energy and various ancillary services are typically procured separately. In some cases, similar products are traded in different markets due to variations in market areas, operators, procurement timelines, etc. Without coordination between these markets, the revenue-stacking potential of SPs may be impacted by factors such as their expertise and transaction fees. A straightforward solution involves establishing market coordination channels, enabling the coordinated procurement of products. In instances where the same product is procured in two different timeframes, a coordinated approach can be applied. Some markets opt to use unselected bids from the first market in the second timeframe instead of conducting a separate bidding session. For example, a previous model used by the California Independent System Operator (CAISO) incorporated unused bids from the day-ahead ancillary service markets into the real-time ancillary service markets [4]. Similarly, in the current Spanish electricity markets, unused bids submitted to the day-ahead (DA) congestion management market are considered for real-time congestion management [30]. In both cases, the second stage (real-time ancillary or real-time congestion management) primarily utilises bids from the first stage

[2] Please note that this is based on the current draft of the network code which is available for public consultation. However, there might be (small or significant) difference with what will be presented in the final network code.

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markets (day-ahead ancillary services and day-ahead congestion management, respectively), with limited or no additional bidding in the second stage.

The bid forwarding process serves as a coordination channel connecting local flexibility markets with wholesale electricity markets. The European Framework Guideline on Demand Response (FGDR), a recently published document, lays down preliminary regulations for the bid forwarding process between local and wholesale markets [15]. Notably, the Norflex project in Norway has effectively implemented the forwarding of unused bids from the local flexibility platform to the balancing markets, demonstrating the feasibility of this process [31]. Another European initiative, CoordiNet, has also developed solutions to facilitate the forwarding of bids from local markets to wholesale electricity markets, aiming to enhance the value-stacking potential for SPs [32].

The EU regulatory framework on flexibility markets is currently under development, with the final network codes expected to be published in the form of a delegated act by 2026. These rules will address demand response and the market-based procurement of non-frequency ancillary and congestion management services and result from a co-drafting process between ENTSO-E and EU DSO Entity, in alignment with the FGDR published by ACER in December 2022 [15]. The analysis on the approaches taken by the demos within three main elements (baselining, prequalification, local markets) and on whether these are aligned with the principles defined by the FGDR was carried out in D3.4 [33]. Apart from this, D3.4 also presents an in-depth analysis of the existing options found in literature and discussion on the different regulatory options based on a multi-question framework. One main conclusion from the deliverable is that, although the benefits of defining a European target-model are not yet certain, there is a consensus on the need for a harmonisation and high-level principles for this current experimentation phase.

The literature analysis presented within the deliverable highlights several options concerning determining roles and responsibilities, processes and minimum technical requirements. It suggests that the choices made ultimately depend on various factors and regional particularities, including the specific market design, existing requirements, the level of coordination and the regulatory framework. Generally, the demo experiences confirm the finding from the literature analysis and there is no clear trend across demos for most market design choices.

One interesting finding from T3.4 is that all the OneNet demonstrators consider prequalification as a mandatory process, not being prepared to replace it by an ex-post verification [33]. This is contrary to the FGDR that considers ex-post verification the default process as replacement for the product prequalification. Demo leaders argue that ex-ante prequalification ensures service reliability and helps SPs to avoid penalties by verifying compliance and capabilities beforehand through activation tests. Some SOs also cite a lack of time to study and implement this new concept due to its recent introduction. Nevertheless, some stakeholders view this change as a simplification, particularly benefiting smaller resources in flexibility markets by reducing the number of activation tests, especially at the unit level. One key conclusion on prequalification is that even though the goal is to harmonise prequalification processes at the EU level in the long term, understanding different positions and possibly allowing various methodologies for different flexibility product types at an initial stage may facilitate the transition to ex-post verification. And this is what is aimed within the NCDR proposal by DSO Entity and ENTSO-E, that was submitted for public consultation in November 2023 [34], and after the drafting of D3.4 [33]. More specifically, the proposal foresees the approval of Union-wide terms and conditions or methodologies when a harmonisation is recommended within the monitoring reports to be developed by ACER. These recommendations shall be built based on best practices and options taken be the Member States, addressing several areas, from which is included the identification of cases where an ex-post verification can be used as replacement for a product prequalification. Hence, this simplification is left open for Member States to propose and test their approaches, with a harmonisation only foreseen when conclusions and best practices can be extracted and recommended.

The FGDR [15] and the NCDR [34] aim to promote a robust, efficient and coherent energy market across Europe, encouraging local market participation in wider wholesale markets while ensuring system stability and efficiency. The analysed documents address the integration and coordination of local markets with wholesale markets, mentioning the high-level principles of transparency, technology neutrality and non-discrimination, and emphasising the following key points

Operational TSO-DSO coordination. The guidelines highlight the importance of promoting effective coordination between TSOs and DSOs to ensure coherence in the interaction across various markets and different time frames. Coherence in the interaction between various markets and different time frames, encompassing scheduling and balancing process. Additionally, the terms and conditions for the overall market design for local SO services require SOs to consider a common pool of bids between coordinated or linked local markets with other central markets. The SO is provided with principles to establish coordination areas, which cover grid elements, users, and connection points that may be affected by or provide solutions to congestion or voltage control issues.

TSO-DSO Interoperability. The guidelines require interoperability and portability between local and other central markets at least on a national level. Interoperability aims to provide cost-efficient access to all markets for both SP and SOs and to further coordinate markets. Moreover, interoperability should aim to provide cost-efficient access to all markets for both SPs and SOs and to further coordinate markets.

SOs are required to share all relevant data with market participants through all relevant platforms, allowing SPs to participate in multiple markets. Market operators must publish information such as market structure, number and clearing of market sessions, gate closure times, and products traded.

TSO-DSO Governance coordination. SOs should consider the national context, such as unit or portfolio bidding, central or self-dispatch, the maturity of market-based local SO services, and the number and structure of DSOs when preparing the common SO proposal for procedures. Market operators of local markets for SO

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services need to ensure neutrality and transparency, in particular with regard to the pricing mechanism and the selection of bids to be forwarded.

On the local market operation, having a MO as a third-party responsible entity allows for a better transparency, neutrality and competition. Nonetheless, FGDR mandates that any third-party MO must be separate from all market activities, such as electricity supply and demand, to ensure fairness and avoid conflicts of interest. Currently, the implementation experience is still limited in the OneNet demo countries, which allowed to understand and compare choices across countries.

3.3 Regulation for harmonising market phases for system services

3.3.1 Regulatory principles for the technical prequalification procedure

The ACERs' FGDR [15] define the prequalification as the process to verify the compliance of a potential service provider with the technical requirements set by the SO for the provision of a SO product (product prequalification) and process to verify the ability of the grid to technically accept the delivery of such a product (grid prequalification). SP qualification checks the SP's capability to deliver a service, including adequate communication tools and data registration. Details on the prequalification process defined are shown in Table 3.1.

Table 3.1: ACER's prequalification procedures definitions [15]

Before the service delivery	**Grid Prequalification** Process aiming at verifying that the delivery of a service can be technically supported by the connecting grid and any intermediate grids.
	Service Provider (SP) qualification Process aiming at verifying the service provider capability to deliver a service having the adequate communication tools or having the SP data correctly registered together with the associated units, among others.
	Ex-ante product prequalification Process aiming at verifying the compliance of the asset(s) of the SP to the technical requirements of the service. ➔ **Ex-ante activation test may be addressed**
After the service delivery	**Ex-post product verification** Process that verifies the compliance of a qualified service provider with the technical requirements set by the SO for the provision of a SO product based on the service delivery and some verification criteria set by the SO ➔ **Ex-post activation test for verification may be addressed**

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Verification test: test whereby the SO sends an activation signal to the SP's assets during normal operating conditions to ensure that in case of need (and favourable market clearing) the resources can actually be activated; their capabilities meet the product requirements and the relevant data can be exchanged. Testing IT and communication requirements are out of the scope of the activation test.

The document from ACER outlines several main principles for designing the prequalification process for System Operators (SO) services, particularly regarding flexibility and demand response. These principles are proposed to ensure an efficient, fair, and transparent prequalification process, facilitating the participation of a wide range of service providers in the market for SO services. These principles include the following key points [15]:

- Transparency and fairness: the prequalification requirements should be public, transparent, verifiable, and accurate. They should also strive to minimise and standardise steps whenever possible, ensuring a level playing field between different types of assets.
- Technical necessity and entry barriers: prequalification requirements should be limited to what is technically necessary to ensure system security and safe grid operation. They should not create undue entry barriers for small units. The requirements can vary among services and products, but standardisation of products should lead to harmonisation of technical requirements.
- Simplification and harmonisation: the new rules aim to simplify and harmonise the prequalification processes, especially for standard balancing products. This includes setting minimum technical requirements, steps, and lead times in prequalification processes.
- Proportionate Burden: the burden of the prequalification process should be proportionate to the size of Service Providing Units (SPUs) or Service Providing Groups (SPGs) and their impact on system security and grid operation in case of non-delivers.
- Avoiding Duplication: The new rules should avoid duplication in prequalification processes, particularly when multiple SOs procure the same product. This includes defining principles and requirements for creating a Table of Equivalences (ToE) between the technical requirements of each product.
- Activation tests: when activation tests are needed, they should be executed by a single SO in cooperation with concerned SOs. The document clarifies which SO executes the test, including when multiple SOs procure the same product. Delegating the task of conducting a prequalification process or activation test to a third party is allowed.
- Minimisation of activation tests: the prequalification activation tests, particularly for small units, should be minimised. For Resource Pooling Groups (RPGs), if technically and practically possible, these tests should be required only on new or changed connection points.

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- Data exchange and coordination: the document emphasises the need for standardised procedures for data exchange in the ex-ante prequalification phase. It advocates for a harmonised method for providing documentation in qualification, prequalification, and ex-post verification processes.
- User-friendly national process: the national process should be easy to implement and user-friendly non-discriminatory, fair, objective, and transparent for both SOs and SPs. The application process for qualification, prequalification, and ex-post verification should be fully digital.

In addition, the EUDSO Entity and ENTSO-E DRAFT Proposal for a NCDR, currently under public consultations, include or better formulates the following principles [34]:

- Consultation and experience-based updates: system operators should consult market participants when setting procedures for product prequalification processes and consider real-world experiences to update requirements and processes in the future.
- Simplicity and fairness: the procedures for product prequalification processes should be as simple as possible, user-friendly, technologically neutral, non-discriminatory, fair, objective, transparent, and strive to minimise and standardise different steps whenever possible.
- Third-party involvement: subject to national regulatory authority approval, system operators may entrust a third party with conducting the qualification process for service providers. The national terms and conditions for service providers should simplify access to systems operator services and avoid duplications when prequalification processes are justified.

Moreover, further emphasis is given to [34]:

- Table of equivalences (ToE): the ToE aims to introduce comparable product and data exchange requirements to enable service providers and prequalifying responsible entities to avoid duplications and optimise registration and prequalification processes.
- Value stacking: the ToE should particularly simplify value stacking for service providers.

3.3.2 Regulatory principles for the baselining procedure

Regarding baselining, OneNet D3.4 concludes that there is no standard methodology that fits all purposes, since baselining methodologies vary according with the product tested in the different demos [33]. Nonetheless, it is very important to balance the three principles of accuracy, simplicity and integrity. Submetering is considered one of the methods to improve baselining, especially in combined DERs, but it is only at early stages of deployment. Also, the proposal for the NCDR foresees and allows different baselining methods to be implemented depending on the aggregation models, the market design, the type of service and the type of resource, leaving to national decision the definition of the general requirements for validation of baselining methods [34]. Nonetheless, harmonisation of these methods it’s still foreseen, but in a next step, based on

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recommendations that should be included within the second and subsequent editions of ACER's monitoring report.

3.3.3 Regulatory principles for the market clearing procedure

FGDR establishes certain conditions for the operation of local markets for system services [15]. The most relevant ones are as follows:

- The market operators should at least publish the following information: structure, number and clearing of market sessions, gate closure times and products traded
- The SOs shall establish a SO coordination area that may be affected by, provide solutions to or need to provide information to forecast, detect or solve, a given congestion or voltage control issue or group of such.
- While facing congestion, the SO shall always choose the most economically efficient option or combination of options to solve it.
- The new national rules should include principles for the procurement and pricing applicable to different products, different time horizons and specific national or local features. The procurement and activation should be market-based, through a process that ensures transparency and the selection of the most cost-efficient resource.
- The new national rules should determine the pricing mechanisms for the market-based procurement of congestion management.
- The new rules should allow that the prices for the activation of the resources could be predetermined in capacity contracted in advance. In such cases, free bidding should be considered in the activation markets.

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4 Product harmonisation assessment

The objective of the product harmonisation assessment is to compare the OneNet harmonised products, their attributes and values to the products being used by the demonstrators (now and expected in the future) and defining the barriers to product harmonisation from the perspective of these demonstrators.

4.1 Introduction to the OneNet harmonised products

One of the goals of OneNet Deliverable 2.2 [9] was to develop harmonised products which address the need for common system services exploiting all network resources. Based on OneNet Deliverable 2.2 [9], harmonised products can be defined as products with a reduced variation, either only in their attributes, or in attributes as well as in attribute values. The six OneNet harmonised products that were developed in OneNet Deliverable D2.2 [9] are the following: (i) corrective local active product, (ii) predictive short-term local active power product, (iii) predictive long-term local active power product, (iv) corrective local reactive power product, (v) predictive short-term local reactive power product, and (vi) predictive long-term local reactive power product. The products and their usages are described in Table 4.1.

Table 4.1: Overview of the OneNet harmonised products and their usages (Source: [9])

OneNet harmonised product	Usage
Corrective local active power	A corrective local active power product is used to react with active power to an unexpected incident that requires correction in less than one hour. It can be used for the provision of services that do not require a location component (e.g., FCR, aFRR or mFRR) as well as location-related services such as congestion management and (potentially) voltage control using active energy.
Predictive short-term local active power	A predictive short-term local active power product is used to solve forecasted problems within the operational planning timeframe. Therefore, activation can be planned ahead which allows the use of flexibility sources that require a longer full activation time and, as a result, increase liquidity. The product is procured in day-ahead and intraday timeframes, primarily with the objective of dealing with forecast challenges. It can be mainly used for congestion management (Day-ahead congestion management) and balancing (FCR, mFRR, aFRR). However, it could also be used for inertia and voltage control.
Predictive long-term local active power	A predictive long-term local active power product is a flexibility product that provides a scheduled service purchased in advance to ensure the network remains secure. The requirement windows for provision of this product will be scheduled (months or years ahead). This product can be procured to deliver congestion management services and, to a less extent, voltage control services that are already pre-scheduled or reserved as an integral part of the of the long- term planning resulting from the organic growth of the network.
Corrective local reactive power	A corrective local reactive power product is procured mainly to solve voltage control issues in real-time. It is activated after an unexpected fault and primarily used for voltage control, even when it could also be used for corrective congestion management.

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Predictive short-term local reactive power	A predictive short-term local reactive power product is procured with a frequency smaller than one month to answer mainly to voltage control issues even if they could be used for congestion management. It is procured in day-ahead and intraday timeframes primarily for voltage control, but it could also be used for congestion management.
Predictive long-term local reactive power	A predictive long-term local active power product is procured to answer mainly to voltage control issues that are already forecasted over a long period of time. It can be used to integrate flexibility into the planning process and can be procured several years ahead primarily for voltage control but also congestion management.

4.2 Mapping of the OneNet harmonised products

In this section, we discuss how the OneNet harmonised products are being used by the demonstrators and if they foresee using the same products in the future. This is the first step of our assessment as explained in the methodology in section 2.1.

4.2.1 Current use of the OneNet harmonised products by the demonstrators

First, a survey was conducted to collect information on the demonstrators' products, the product attributes, and corresponding values. As the products used by the demos should in theory be identical to the OneNet harmonised products, the former are mapped against latter to see if, in practice, this was indeed the case and, if the attributes and/or values deviated from the harmonised products, what the reasons behind these deviations were.

Figure 4.1 provides a graphical overview of the OneNet harmonised products that were used by each of the demos[3].

[3] Some demos also used aFRR, mFRR, RR and inertia products in their demos but as most of these are already harmonized at European level, they will not be part of this assessment.

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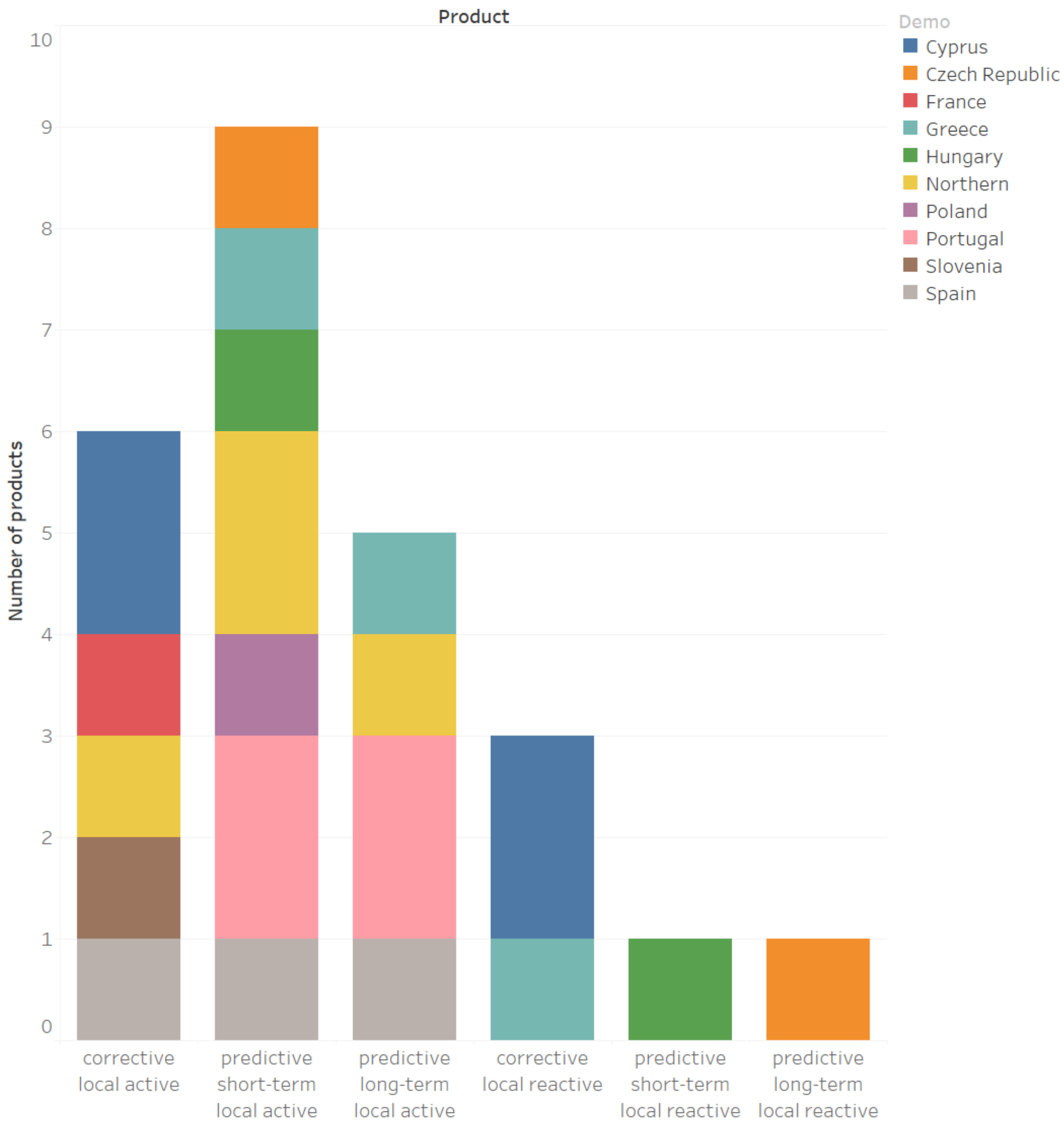

Figure 4.1: Overview of the OneNet harmonised products per demo

From Figure 4.1, it is clear that active power products are used more often than reactive power products. The most used product is the predictive short-term local active power product. As mentioned before, this product deals with forecasted challenges and is mainly used for congestion management and balancing.

Then, Table 9.1 to Table 9.6 in Appendix provide, for each OneNet product, an overview of the attributes, and for each attribute the corresponding harmonised OneNet attribute value and the value provided by the demos (if and when they were using the product in their demo). The demo values that do not correspond with the proposed OneNet values are highlighted in yellow. The table overview indicates that, for most of the products, the proposed OneNet values were taken. Where the values diverge, an explanation was offered by the demos. More specifically, in the case of the Northern demo, the attribute values diverged because the bids

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might be forwarded to the MARI platform and, hence, the attribute values must comply with the MARI platform requirements. Then, for the Cypriot demo, some of the values for the corrective local active product were provided in MVA instead of MW because this product was also used as a reactive product, where some of the attribute values were provided in MVA. For the Slovenian demo, the corrective local active product was designed with the very specific nature of the local context in mind, where a specific amount of flexibility was needed and only one SP was able to deliver the product. This, for instance, also explains why there was no granularity attributed to the product. For the Hungarian demo, some small values were detected for the predictive short-term local active product for reasons of the residential electric water heaters that are directly controlled by the DSOs. The electric water heaters shall be able to be take part in the LV network congestion mitigation in the future of the market, hence they should be able to participate one by one as an asset even though they are considerably small loads. Finally, for the Polish demo, as the predictive short-term local active product is only to be used by the DSO, the demo opted for a small granularity, namely 1 kW instead of 1 MW for TSOs and 0.01 MW for DSOs. Finally, some demos did not actively trade products in their demo but were focused on the development of a market (e.g., Czech demo) or technical coordination platform (i.e., Portuguese demo and French demo). Therefore, the product attribute values were not relevant and, hence, not defined.

4.2.2 Future view on OneNet harmonised products

Another question in the survey to the demo's was if they were planning to use the OneNet harmonised products after the OneNet has ended. Table 4.2 provides an overview, per demo, of the plans to keep using the demo products.

Table 4.2: Overview of planned post-OneNet product use of the OneNet products per demo

Product	Usage post-OneNet and reason for decision
Northern demo	
NRT-P-E (Near Real Time Active Energy)	Not decided yet. The product follows the MARI product requirements, so in that sense it will be anyhow implemented in the near future. The novelty using the product is the connected resource group reference to the flexibility register, and thus the enabling of local congestion management use and bid filtering.
ST-P-E (Short Term Active Energy)	Not decided yet. But the need for such product is emerging.
LT-P-C/E (Long Term Active Capacity/Energy)	Same reason as above.
ST-P-C (Short Term Active Capacity)	Yes, in Finland, the mFRR capacity product will be in place when the transfer to the 15 min mFRR products is realised. Independently from the OneNet project for mFRR capacity procurement, this product is implemented in Estonia, Latvia and Lithuania as well.

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Product	Usage post-OneNet and reason for decision
	The ST-P-C product can be used to procure capacity from D+1 till month ahead. Thereby, for the mFRR capacity market, the ST-P-C tender would be closed and opened on a daily basis to procure capacity for the day-ahead.
Cypriot demo	
Change of active power (i.e., load shifting, peak shaving)	No. Immature electricity market in Cyprus does not allow at this time the use of such products by the end of the OneNet project. Furthermore, there is not any flexibility market established yet in Cyprus.
Phase balancing	No. Immature electricity market in Cyprus does not allow at this time the use of such products by the end of the OneNet project. Furthermore, there is not any flexibility market established yet in Cyprus.
Change of reactive power (i.e., voltage regulation, reactive power compensation)	No. Immature electricity market in Cyprus does not allow at this time the use of such products by the end of the OneNet project. Furthermore, there is not any flexibility market established yet in Cyprus.
Greek demo	
Reactive support	No. Currently, there is not an established flexibility market in Greece, neither a complete regulatory framework for its establishment. The current approach for congestion management and voltage control involves proper unit dispatch and shunt element activation based on a static security assessment according to the N-1 criterion. In addition, the TSO-DSO coordination is not yet fully defined (no existing platform and complete regulatory framework). Therefore, those reasons burden the use of such products (congestion management and voltage control nature) in the near future within the existing market in Greece despite their well-defined attributes.
Predictive congestion management for TSO/DSO product	Same reason as above
French demo	
Near real time corrective local active energy	Yes, the French demo considered already existing product and compensation mechanism that should still be in use post-OneNet.
Portuguese demo	
Products for Intraday Congestion Management for DSO/TSO	Currently there is no established flexibility market operational in Portugal, and the technical rules are yet to be defined, so there is no expectation on the use of these products in real markets. However, a pilot project for flexibility market operated by the DSO will take place in the following years, among others, it will incorporate the "secure" product.
Products for Day-Ahead Congestion Management for DSO/TSO	
Sustain	
Secure	

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Product	Usage post-OneNet and reason for decision
Spanish demo	
Corrective local active	Pending of regulatory rules. Currently, there is no standard business model and procurement process for DSOs to implement flexibility products in Spain
Predictive short-term local active product	
Predictive long-term local active	
Czech demo	
Local congestion management of active power	This product is expected for regular use – details will be specified when both EU and national regulation of flexibility is in place.
Voltage Control by Q management / Reactive Power Management	Reactive power-based flexibility products are now in use – the tested IT solutions is expected to streamline its use.
Hungarian demo	
Change in active power (P) (CM & VC)	Yes
Change in reactive power (Q) (CM & VC)	No, there are no significant reactive issues on the MW level distribution network.
Polish demo	
Change in active power (+ & -) (CM + VC)	Necessary regulatory framework to use such products is during implementation. Experience from OneNet tested product is used for national implementation.
Slovenian demo	
Congestion management and Voltage control via aggregator through a market platform	Yes, but with different product attribute values. The reason for this is that there will be adjustments to baseline calculation and product definition to include increasing consumption (currently there is only reduction in consumption). Moreover, there will be changes to the business model to include pricing for capacity offerings as currently aggregators only get paid for delivered energy.

From the survey answers, there are no clear tendencies towards either the continuation or discontinuation of the use of the OneNet harmonised products. It depends on the specific situation of the demo: the local needs, the (absence of) regulation, the existing markets, etc.

4.3 Barriers to product harmonisation

4.3.1 General overview of the barriers

As EU regulation foresees a certain level of product harmonisation in the future (see Section 2.1), the second step in the product harmonisation assessment was to bring together the barriers preventing product harmonisation, to better understand what conditions need to be in place (or removed) to foster product harmonisation. To this end, Table 4.3 provides an overview of the general barriers to product harmonisation, divided over four categories, i.e., technical, economic, regulatory and social.

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Table 4.3: Overview of the general barriers to product harmonisation, explained per category (Source: [9], [11], [12]

Type of barrier	Barrier
Technical	The very specific nature of the grid need, and/or **structure/technology of the grid** in a specific market area imposes restrictions on the values of certain attributes or the use of certain products or makes harmonisation unnecessary.
	Different levels of maturity of SOs in the procurement of the flexibility from SPs can pose another barrier. More specifically, TSOs are typically well accustomed to EU harmonisation (e.g., balancing platform PICASSO, MARI and TERRE, standard balancing products) while DSOs are just beginning to develop markets and products for local services.
	ICT challenges do not allow for an exchange of information; hence cooperation is impossible and there is no option to harmonise products.
	The needs the product should cover are unclear for one or more SOs, hence, it is difficult to harmonise products, attributes and their values.
	Diverging requirements for different services for different SOs make harmonisation impossible.
Economic	The **stage of market development** is different for the different system services and SOs, e.g., balancing products versus products for local services such as congestion management and voltage control.
	The **stage of the product life cycle in the market** is different for the different system services and SOs. Such differences in life cycle stages usually call for adaptations of "home country" approaches. More advanced product users could resent adapting "out-of-date" attribute values for attributes while less advanced ones could perceive some attribute values as too demanding.
	The **level of competition/liquidity in the market** could suffer due to product harmonisation. If the needs of a certain service are too specific, mostly due to local circumstances such as the specific design and state of the grid, product harmonisation could prevent service providers from entering the market.
Regulatory	It is a **political choice** (by different stakeholders such as regulators, SOs, SPs, BSPs, etc) to not harmonise products and attribute values.
	The **national grid code or other regulation imposes certain limitations**, or the necessary specifications are not included (yet).
Social	**Contextual differences** between countries and stakeholders do not allow for harmonisation.

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4.3.2 Product harmonisation barriers applied to the demos

The last question in the survey to the demos was which of the general barriers listed in Table 4.3 they would foresee to be applicable in their country. In the sections below, for each the demos, we provide a table of the relevant barriers for a specific demo region/country and reasoning for this. Finally, Section 4.4 provides an overview of the occurrence of the different barriers in the demo countries with the goal of pointing out which product harmonisation barriers are the most important to overcome.

Northern demo: product harmonisation barriers

Barrier name	Reason
Structure of the grid	Towards lower voltage levels the level of minimum bid size is requested to be lower (e.g., 10 kW) while for balancing the current practice is 1 MW. In addition, the activation response requirements may be different at different hierarchy levels of the grid, for instance, due to PV installations in particular in LV or MV grid, whereas transmission grid follows more wind power penetrations.
ICT challenges	Access to and exchange of relevant grid information which is needed for qualification and optimisation processes. Usage of standardised data models and formats. Different maturity stages of data hubs (i.e., access to main meter data). Definition of and access to sub-meter data. This also pertains to ex-post flexibility verification and settlement at resource level.
Diverging requirements	Similar to the first barrier (i.e., structure of the grid).
Political choice	Even more, it will be a challenge to foresee the same products throughout the region. There are efforts towards a uniform electricity price at the regional level, e.g., Nord Pool system price vs area price. TSOs have commitments to remove inter-zonal congestions and have same price in the area covered by the Nord Pool. Then why not harmonised market products at SO level?

Cypriot demo: product harmonisation barriers

Barrier name	Reason
ICT challenges	The implementation of the ICT infrastructure to support the products' activation is a considerable barrier. This is applied to all the products. Especially the ICT infrastructure barrier is more pronounced in the distribution level (most in low voltage levels) where the activation of products from flexible household consumers should be done and usually is not supported by the ICT infrastructure.
Economic development	The market in the Cyprus power system is still pre-mature and needs some time to accommodate flexibility products that can be addressed from SPs.
Competition - liquidity	This is again a barrier in the case of the Cyprus demo since market is still not operational and therefore the increase of liquidity in the operational market will take some time.
Regulatory limitations	In Cyprus, potential barriers are due to national grid code restrictions on connecting battery storage systems to the grid, currently under revision. This limitation may hinder real-life implementation of products based on active power (ΔP), reactive power (ΔQ), Phase balancing, and frequency support, which benefit from energy storage systems.

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Greek demo: product harmonisation barriers

Barrier name	Reason
SO market maturity	There are no existing flexibility markets related to congestion management and voltage control services for both SOs. Moreover, the TSO is more mature when it comes to frequency related products – the existing balancing market that is operated by the TSO is mature.
ICT challenges	There is a lack of submetering infrastructure and TSO-DSO coordination interfaces.
Diverging requirements	There is a lack of TSO – DSO coordination mechanisms, regulatory rules, and existing interfaces. AS there are no common defined rules, there is no common approach for the different needs of the SOs and, hence, there are diverging requirements (location, periods, granularity, etc)
Regulatory limitations	There is a lack of regulation regarding a flexibility market operation and no existing flexibility market. There are no TSO-DSO coordination schemes defined. A common flexibility registry, common product attributes, prequalification process, and type of information exchange (there is an initial regulatory attempt) need to be defined. Remuneration schemes between aggregators, SPs, and SOs need to be further defined. There is a lack of submetering regulatory framework. There are no formalised rules for submetering in Greece and there has also been a significant delay in the smart meter installations to replace conventional meters, due to objections to the tendering procedure Additionally, there is a lack of regulation regarding mechanisms for procurement of flexibility (only in balancing market – auction-based – for frequency products) There is a lack of regulation that protects agents from market abuse by incumbent access to information.

French demo: product harmonisation barriers

Barrier name	Reason
Structure of the grid	Due to the local needs for congestion management, and the near real time condition.
SO market maturity	Current mechanisms may be too simple to embed them
ICT challenges	New data model needed to use the products
Competition - liquidity	Too complex products might deter producers form participating

Portuguese demo: product harmonisation barriers

Barrier name	Reason
Structure of the grid	This is an issue especially when considering very local issues from the DSO side.
SO market maturity	This is an issue especially when taking into account that, from the DSO perspective, it is new territory.
ICT challenges	It requires a data model able to adequately represent the different products
Diverging requirements	Requirements (attributes) that fit TSO needs may not be adequate to solve DSO problems, e.g., minimum bid size.

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Economic development	This is an issue especially taking into account that, from the DSO perspective, it is new territory.
Competition - liquidity	From the DSO perspective, harmonised products can have impact on the liquidity of markets, as they may exclude participation from certain SPs.
Regulatory limitations	From one side, there is the European network code on demand response that is still under development, and from the national point of view, the technical rules for flexibility provisioning is not implemented yet.

Spanish demo: product harmonisation barriers

Barrier name	Reason
Structure of the grid	All products – not in all the cases will be possible to use harmonised products because of the nature of the grid
SO market maturity	All products – these can affect the time of implementation at national level
ICT challenges	All products – for service providers and SO to have the technologies to implement the products
Diverging requirements	All products – different requirements between TSOs and DSOs
Competition - liquidity	All products – SPs need to have some economic incentives to participate. Without those it is going to be difficult to have market liquidity to buy the products
Regulatory limitations	All products - Currently, there is no standard business model and procurement process for DSOs to implement flexibility products in Spain.
Contextual differences	All products – This can affect the motivation for participating in the markets

Czech demo: product harmonisation barriers

Barrier name	Reason
Structure of the grid	Grid topology and other conditions might be different, but in principle grid issues are similar which means that even products are not so diverse/unique.
SO market maturity	Again, technological preparedness may represent the major obstacle in the flexibility procurement.
ICT challenges	To enable cooperation of systems from different companies/market parties there must be overcome certain difficulties concerning SCADA and market environment interface
Competition - liquidity	Partly, non-frequency services are closely related to the part of the grid. Therefore, in certain, places liquidity/competition can be lower or impossible.

Hungarian demo: product harmonisation barriers

Barrier name	Reason
Structure of the grid	Variable structures and issues depending on the geolocation and participants.

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SO market maturity	Low maturity. The market has just started.
ICT challenges	SOs are the DSO, there are multiple companies with various ICT systems. IT integration and harmonisation are a long and resourceful processes.
Competition - liquidity	Low maturity. The market is just started.

Polish demo: product harmonisation barriers

Barrier name	Reason
SO market maturity	DSOs that have participated in flexibility projects are aware of the problems
ICT challenges	The basic requirement for predicting and identifying constraints is having an accurate MV and LV network model and powerful IT tools, which is currently a problem. Because of this, the limitation is dynamic determination of the demand for flexibility services, the use of which would remove the congestions.

Please note that the responses of the Polish demo surrounding the barriers are fragmentary and refer only to predictions based on the current regulatory framework and regulatory developments that are under development. More specifically:

The process of implementing Directive 2019/944 [35], i.e., on flexibility (Article 32) is in its final stages, waiting for the regulations to come into force. This implementation provides for the development of standardised market products at the national level for the provision of flexibility services. The discussion about what these products will be is only just beginning. Undoubtedly, the Polish stakeholders will use the experience gained in the OneNet project, but it should be taken into account that only one DSO (EOP) participated in the project. The experiences and needs of other DSOs may be different.

1. The Polish power system is a central dispatching model system, which means that the TSO solves congestion problems in its network by using balancing offers under the so-called integrated scheduling process. This means that the TSO will not use additional SO services to solve congestion problem.
2. According to the definition in the new law, flexibility services are addressed only to DSOs in order to solve congestion problems with the use of resources connected to the LV and MV network.

Slovenian demo: product harmonisation barriers

Barrier name	Reason
Structure of the grid	DSO has different needs than TSO. But all DSOs should have the same needs
ICT challenges	Each DSO has its own back-end IT system in regard how it processes and stores data and operates the system.
Economic development	Some DSOs are more advanced in market development than others.
Product life cycle stage	Some DSOs already operate the demos, some are not included.
Competition - liquidity	Only some players can overcome initial entry market costs.

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Overview of product harmonisation barriers as from OneNet demonstrators' perspective

Table 4.4 presents an overview of the barriers and whether they were deemed relevant for product harmonisation by the different demos.

Table 4.4: Overview of relevant barriers to product harmonisation for the different demos

Barrier name	NOC	CYP	GRC	FRA	PRT	ESP	CZE	HUN	POL	SVN
Structure of the grid	Y	N	N	Y	Y	Y	Y	Y	N	Y
SO market maturity	N	N	Y	Y	Y	Y	Y	Y	Y	N
ICT challenges	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Unclear product needs	N	N	N	N	N	N	N	N	N	N
Diverging requirements	Y	N	Y	N	N (TSO) Y (DSO)	Y	N	N	N	N
Economic development	N	Y	N	N	Y	N	N	N	N	Y
Product life cycle stage	N	N	N	N	N	N	N	N	N	Y
Competition/ liquidity	N	Y	N	Y	N (TSO) Y (DSO)	Y	Y	Y	N	Y
Political choice	Y	N	N	N	N	N	N	N	N	N
Regulatory limitations	Y	Y	Y	N	Y	Y	N	N	N	N
Contextual differences	N	N	N	N	N	Y	N	N	N	N

Moreover, when we plot the number of times the barriers were deemed relevant on a radar chart in Figure 4.2, it is clear that ICT challenges together with structure of the grid, SO maturity and the competition/liquidity are the most important barriers for product harmonisation at this stage in time.

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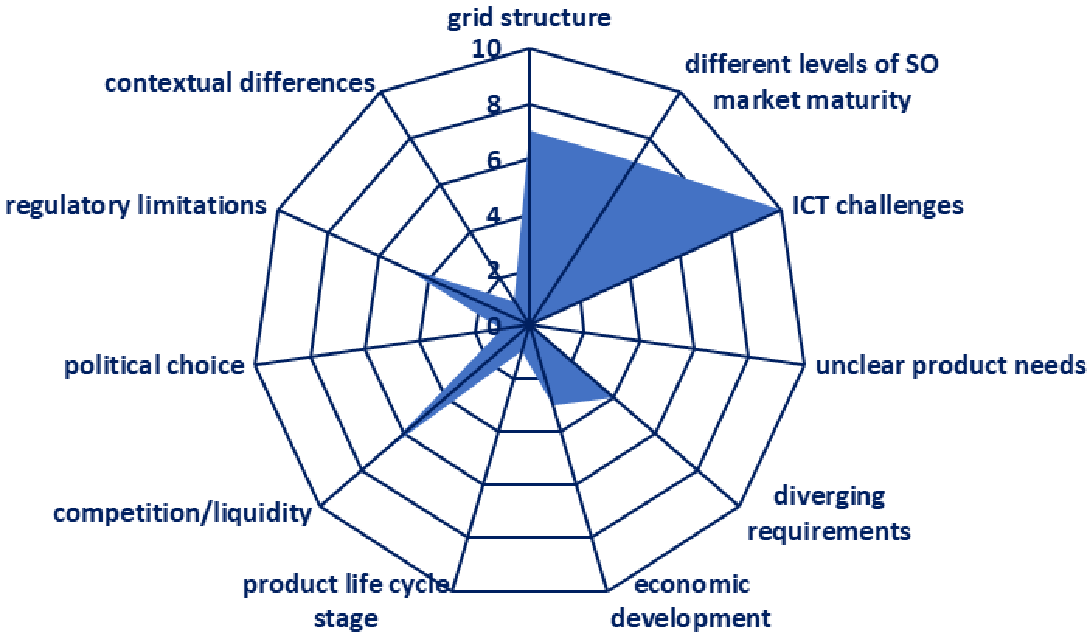

Figure 4.2: Radar chart of the product harmonisation barriers

When we compare, for these four main barriers, the different causes provided by the demos, we can summarise them as follows. **ICT challenges** have different sources. First of all, not all technologies that are needed are available. For instance, there is a lack of submetering and/or access to the submeter data. There is also a lack of access to and exchange of grid information, which is also linked to accurate LV and MV grid models. Moreover, even when data is available, there is the lack of standardised or interoperable data models, for TSO-DSO coordination but also for SP-SO market interfaces for instance. Especially at DSO-level, there is a lot more diversity in IT systems, e.g., with regard to how data is processed and stored and how the system is operated. The barriers concerning **grid structure** are mostly related to the local issues on the DSO side and the different impact of activation on different grid levels (LV versus MV versus HV). Then, with regard to **different levels of maturity of SOs in the procurement of the flexibility from SPs**, the demos confirm what was mentioned in the general overview, namely that there are very limited markets related to congestion management and voltage control, and that the concept of markets for system services is still new for DSOs. This means that there is currently limited DSO experience with regard to developing products for these services and that it is, hence, difficult to correctly estimate the system needs and what such products should look like. This, in turn, implies that it is difficult to harmonise products, for instance, with a view on TSO-DSO coordination for joint procurement of (the same of similar) system services, or for harmonisation (at the local/national level) of DSO markets and products. Finally, when it comes to increasing market competition and liquidity, the demos confirm that some products might be too complex and that there might be a need for a more bespoke approach as the

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product definition is very much linked to the structure of the grid and specific needs of the systems services, which might differ a lot at the local, lower voltages levels.

4.4 General recommendations for product harmonisation

Figure 4.3 provides an overview of the product harmonisation assessment.

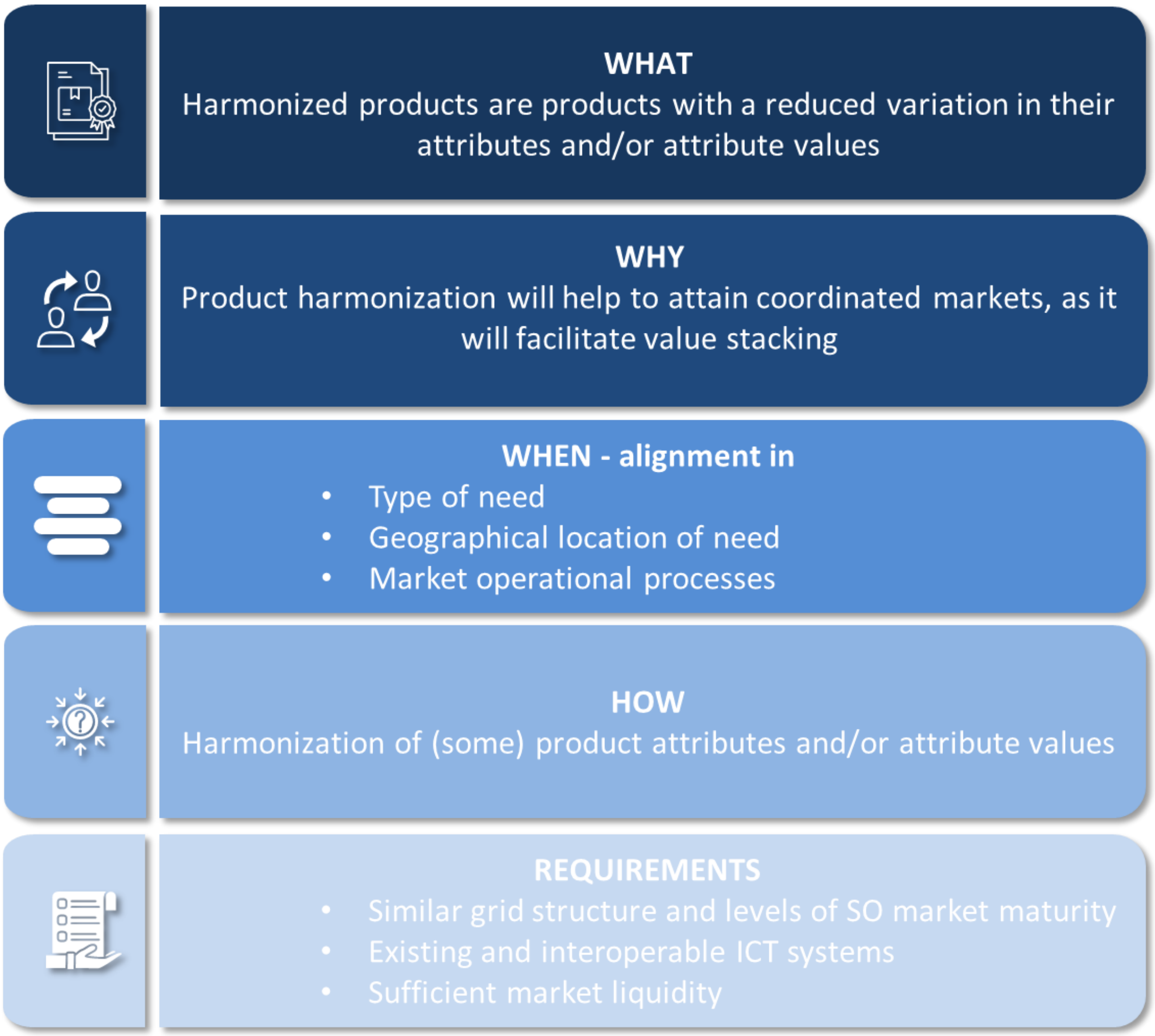

Figure 4.3: Overview of product harmonisation assessment

Figure 4.3 can be explained as follows. First of all, harmonised products are products with a reduced variation in their attributes and/or attribute values [9]. Based on the objectives of coordinated and integrated markets, as well as the barriers to reach these objectives that were defined in OneNet Deliverable 3.2 [36], the aim of product harmonisation is to help the attainment of coordinated markets, as it will facilitate the maximisation of value stacking, resulting in an efficient allocation that maximises the value of the flexibility. Of course, product harmonisation is not a one-size-fits-all approach. It adds value only when there is an alignment in needs. More

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specifically, there needs to be an alignment in the type of need or type of service. This could be the same service, for instance mFRR services, or similar services, for instance active power for congestion management and balancing. Next to an alignment in the type of need, there should also be an alignment in geography. This means that the needs should cover the same geographical area or different areas with similar grid characteristics. Finally, there should be an alignment in market operational processes, i.e., an alignment in market timing and/or some degree of coordination between markets (this could range from an exchange of information to coordination in the form of different TSO-DSO coordination schemes, see also [14]). Product harmonisation can be achieved by harmonising (some) product attributes and/or their values in the different geographical markets where these products would be used. However, in this regard, the TSO-DSO roadmap to distributed flexibility [37] states that, as flexibility services such as congestion management, are addressed through different mechanisms in different Member States, a European harmonisation of the products is not required but that some principles and a list of attributes could be designed at the EU level to reduce barriers for market parties who want to provide flexibility in different EU markets and gain sufficient alignment with balancing and wholesale markets. As mentioned before, the draft NCDR only aims for product harmonisation at the national level for specific balancing products and active power products for congestion management and voltage. However, it does foresee a European list of product attributes. Finally, a number of theoretical barriers to product harmonisation were provided. When discussing with the demos which of these barriers they would expect, four major barriers were identified. Hence, to make product harmonisation possible, the following requirements need to be in place: (i) a similar grid structure and (ii) level of maturity of the SOs, (iii) existing and interoperable ICT systems for data exchange and communication/information, and (iv) a market that is already sufficiently liquid and competitive.

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5 Market architecture harmonisation assessment

In this section, we evaluate the potential for harmonising market architecture by assessing the feasibility of bid forwarding between local and central markets. Bid forwarding analysis builds on the detailed description of the market architectures in terms of the pillars and features as the one defined by the Theoretical Market Framework proposed in OneNet [16], [38]. The insights derived from the bid forwarding analysis presented in this document have led to the formalisation of an updated version of the OneNet TMF, incorporating features relevant to describing the bid forwarding process. This document presents the updated version of the TMF and describes the relevant OneNet demonstrators accordingly. The fundamentals of bid forwarding and an example of application of the bid forwarding analysis are presented in OneNet Deliverable 3.3 [14]. In this document, we expand on these concepts by providing details of the methodological approach to bid forwarding analysis and, through analysis of the OneNet demonstrator solutions, explore the potential for market architecture harmonisation in the OneNet demo countries.

It should be noted that both local and central market design features discussed in this analysis may differ from those in effect at the time of this document's publication. These differences are largely due to the ongoing regulatory changes at the central market level, particularly balancing, and corresponding adjustments in the local market designs. Therefore, the analysis performed here is based on the market design features detailed in the tables and should be considered illustrative rather than conclusive results.

5.1 Theoretical Market Framework with bid forwarding features

The intricacies of the electricity sector and the novel elements introduced by the ongoing energy transition necessitate the use of market design and analysis support tools for systematic categorisation of market concepts. This, in turn, facilitates further analysis and a clear and unambiguous communication through the use of precise terminology.

In the context of the OneNet project, a comprehensive Theoretical Market Framework (TMF) is proposed to support the analysis of existing markets and guide the design and integration of novel markets for procuring system services. The adoption of the TMF allows describing the market architecture by means of a set of pillars, features, and sub-features and identifying the corresponding design options. A detailed description of the fundamentals of the TMF and its application for the analysis of the OneNet demonstrator is available in [16], [38]. The TMF description of the OneNet demonstrators represents a preliminary condition for addressing the bid forwarding analysis since allows identifying the relevant market design features that enable the submarkets' coordination [13], [14].

Figure 5.1 shows the overall structure of the TMF, which consists of five pillars, each with different characteristics [5], [16]. These pillars are: (i) entire market architecture, (ii) sub-market coordination, (iii) market

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optimisation, (iv) market operation, and (v) network representation. Some pillars' attributes are market-wide, explaining how sub-markets' coordination work, while others are specific to individual sub-markets. Market design and analysis requires systematically assessing each pillar and the corresponding attribute for each feature or sub-feature. In this document, an updated version of the TMF presented in [5], [16] is presented. To grant self-consistency to this document, a detailed description of the new elements and reformulated definitions, together with a briefer description of the already established elements of the TMF is provided below.

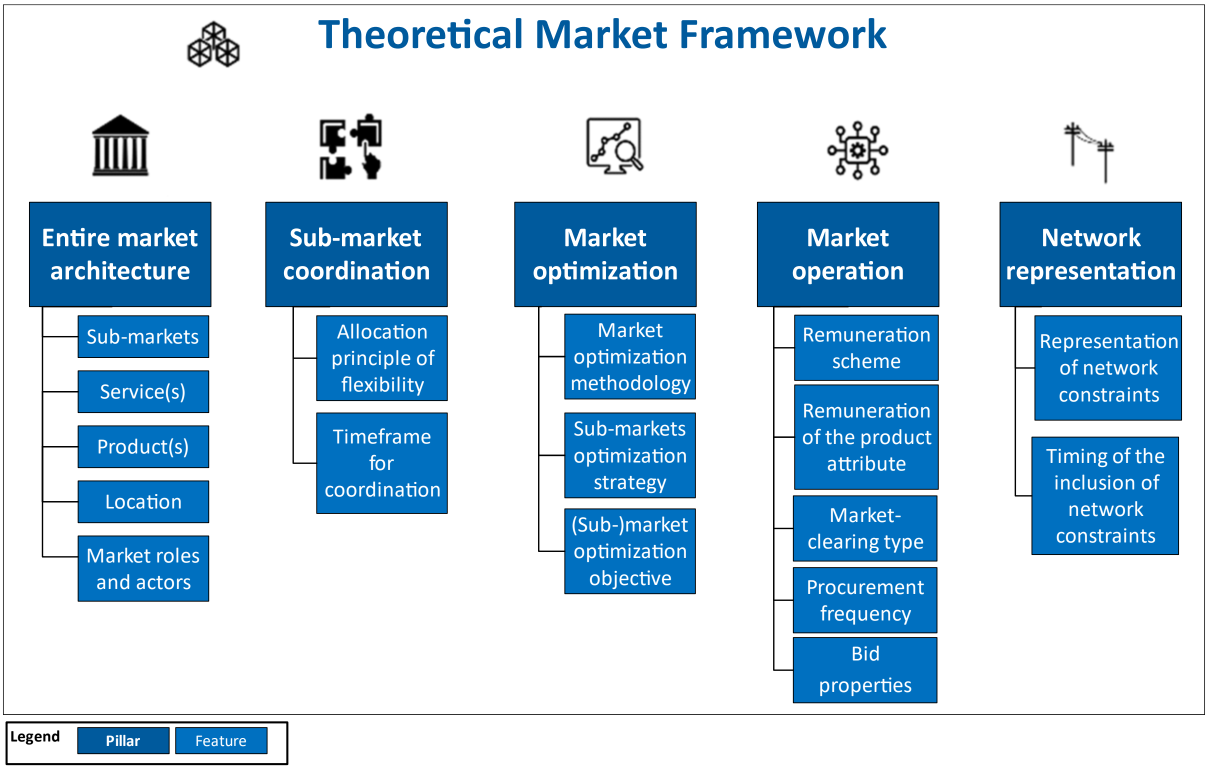

Figure 5.1: The OneNet Theoretical Market Framework (adapted from [5], [16])

5.1.1 Entire market architecture pillar

The 'Entire market architecture' pillar contains all those features that define the high-level characteristics of the market architecture as a whole. The structure of the 'Entire market architecture' pillar is depicted in Figure 5.2. With respect to the TMF proposed in [5], [16], the 'Sub-markets' pillar includes three new sub-features to improve the definition of the time-dimensions related to the entire market architecture, these sub-features are:

- Gate Opening Time (GOT)
- Gate Closure Time (GCT)
- Market Time Unit (MTU)

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Moreover, the ‘Product(s)’ feature is updated by defining two sub-features:

- Type of product
- Technical requirements

The 'Type of product' options are derived from the electricity markets' product list. The 'Technical requirements' section encompasses all the technical properties that define a product based on the system service for which it is procured.

The ‘Market roles and actors’ features contains three new sub-features to capture with more details the market participants:

- Allowed technologies
- Aggregation method
- Aggregation mix allowed

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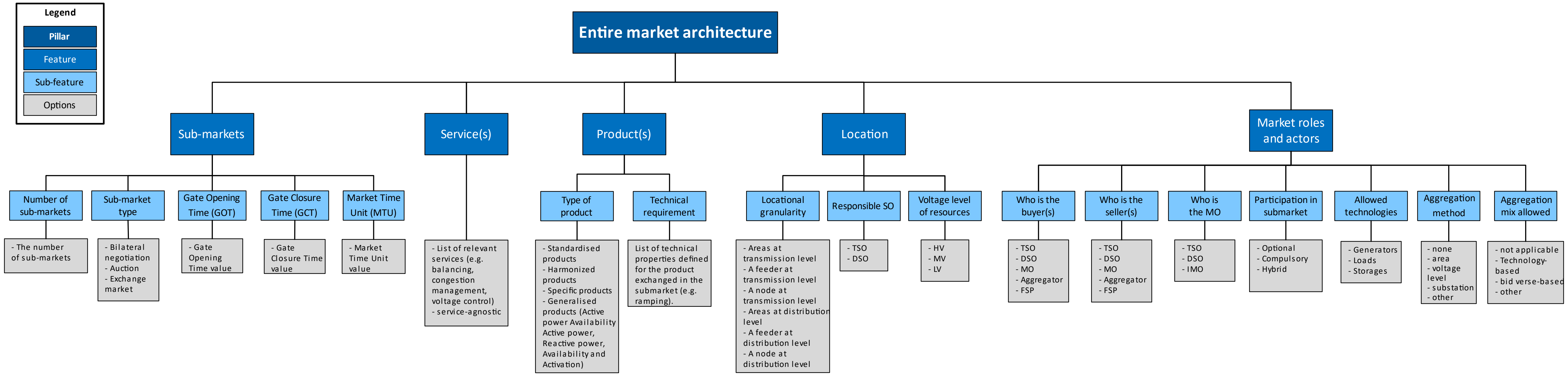

Figure 5.2: Entire market architecture pillar, adapted from [5], [16]

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5.1.2 Sub-market coordination pillar

The 'Sub-market coordination' pillar is formed by features that allow describing how the sub-markets may interact considering the allocation of the common resources. The structure of the 'Sub-market coordination' is available in Figure 5.3 [5], [16].

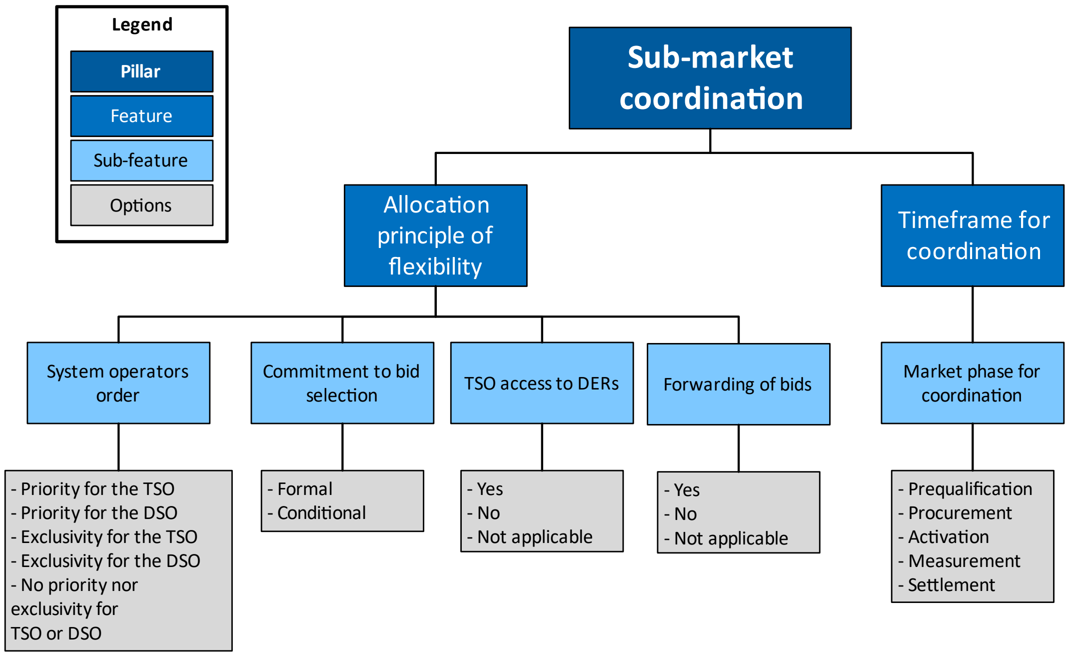

Figure 5.3: Sub-market coordination pillar [5], [16]

5.1.3 Sub-market optimisation pillar

The 'Market optimisation' pillar contains the features that define how a sub-market is cleared and how the clearing process relates with other sub-markets in the market architecture. The structure of the 'Market optimisation' is available in Figure 5.4 [5], [16].

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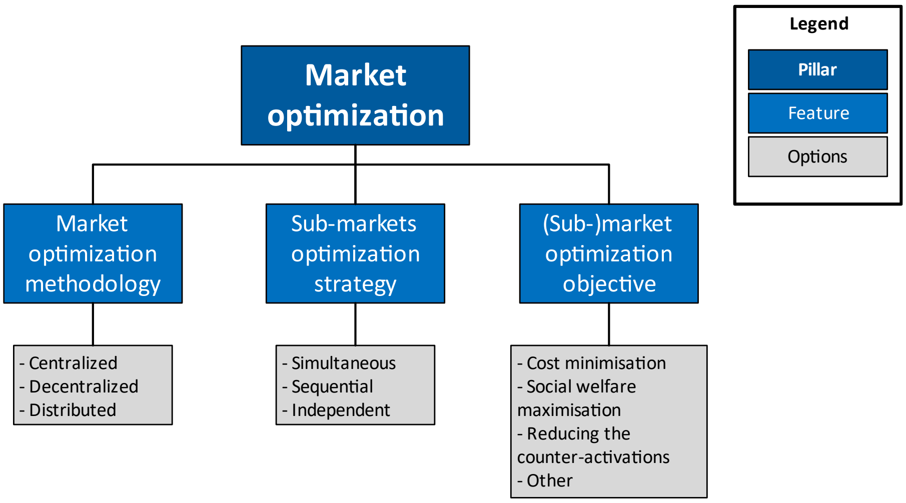

Figure 5.4: Market optimisation pillar [5], [16]

5.1.4 Market operation pillar

The 'Market operation' pillar defines the features that describe the operational aspects of each sub-market [5], [16]. The structure of the 'Market operation' is available in Figure 5.5. The TMF proposed in this document contains 'Bid properties' as additional feature. This feature allows describing market operational aspects related to the nature of the bids accepted in the sub-market by means of the sub-features:

- Minimum bid size
- Bid structure

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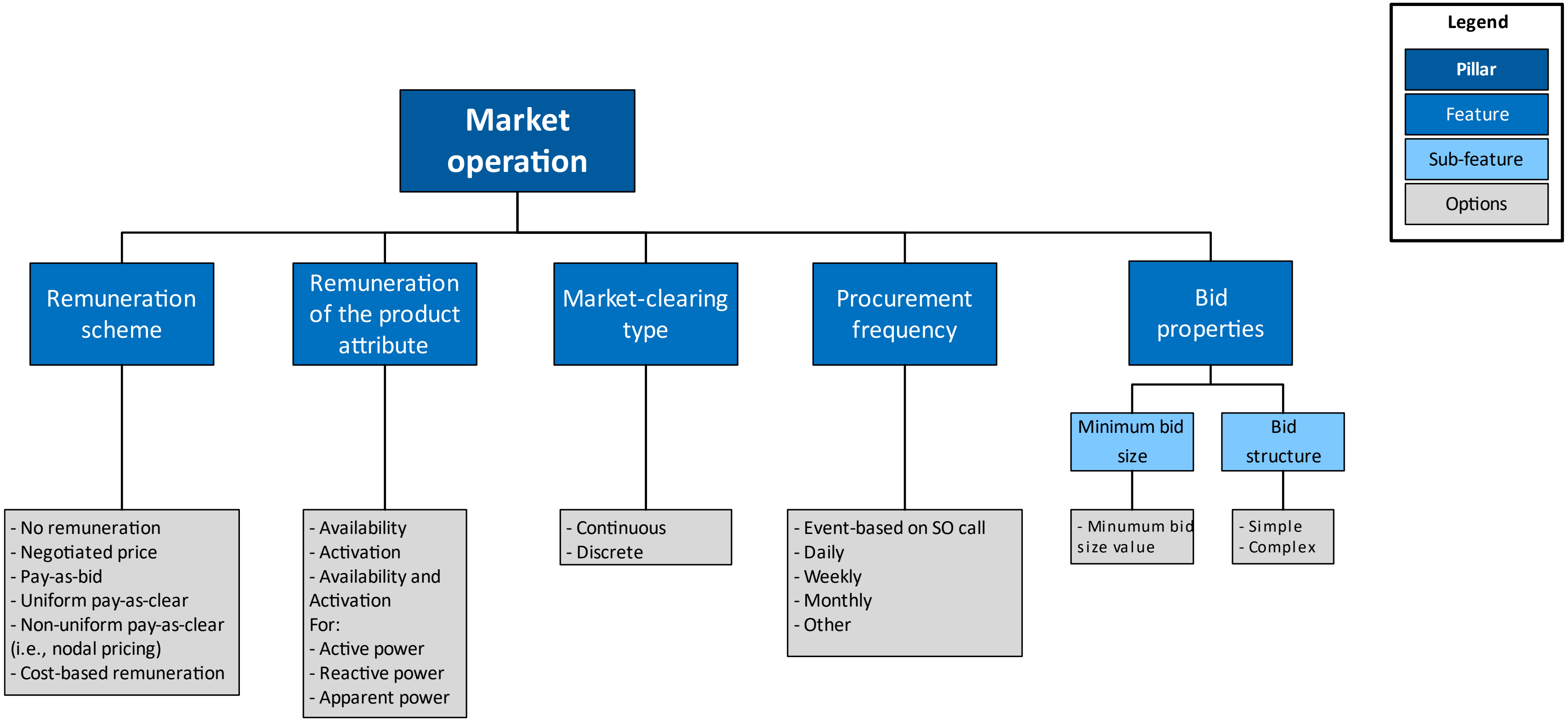

Figure 5.5: Market operation pillar, adapted from [5], [16]

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5.1.5 Network representation pillar

The ‘Network representation’ pillar relates the properties of the market architecture that define how and when the network representation is considered in the market architecture. The structure of the ‘Network representation’ is available in Figure 5.6 [5], [16].

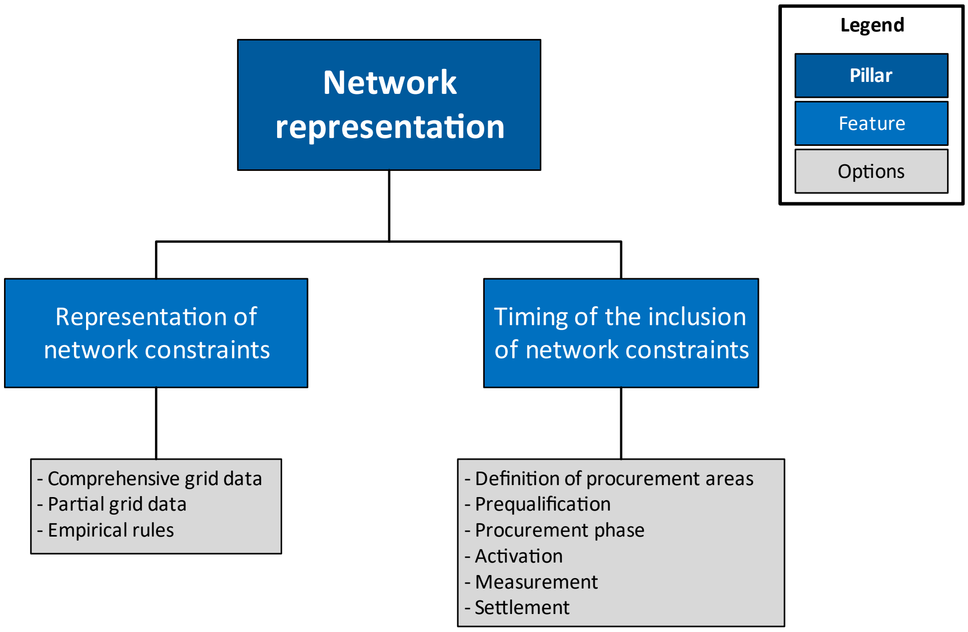

Figure 5.6: Network representation pillar [5], [16]

5.1.6 Demonstrators’ market design

In this document, the market design of the OneNet demonstrators dealing with market-based coordination is analysed. In this section, a detailed description of the market architectures of the demonstrators is provided through the updated version of the TMF to facilitate the bid forwarding analysis described in section 5.2.

The market architectures of OneNet demonstrators, as described using the TMF, include Poland, the Czech Republic, Hungary, Spain, and the Northern Cluster.

Table 5.1 reports the formalised nomenclature used for some of the key elements for the TMF description.

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Table 5.1: Formalised nomenclature for naming the main submarkets. Source: OneNet Deliverable 3.1 [38]

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

Spanish demonstrator market architecture

The Spanish demonstration uses market-driven coordination between DSOs to ensure that the flexibility provided by DERs meets specific local congestion management needs while minimising any impact on other areas [39], [40]. The demonstrators use a local market where the DSO has exclusive access to DERs. While the demonstrator does not directly test the interaction with the TSO, this interaction is considered in the theoretical design of the technical or market-based coordination.

The local markets include long-term and day-ahead availability and activation markets, as well as an intraday real-time activation market. In the case of availability markets, the specification of the number of expected activations is required to assess the total procurement cost. The SPs selected in the availability market, if activation has not been contracted in advance, must compete with other SPs in the relevant activation market to ensure that the lowest bids are selected.

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Parallel to the local markets, sub-markets are already established, as shown in Figure 5.7: day-ahead and intraday energy markets and balancing and TSO congestion management markets. The integration of the local short-term markets with the existing markets is an open task outside the scope of the Spanish demonstrator. However, the potential connection of the local markets demonstrated in the Spanish OneNet demonstrator is theoretically investigated in OneNet Tasks 3.3 [14].

Parallel to the local markets, sub-markets are already established, as shown in Figure 5.7: energy day-ahead and intraday markets and the balancing and TSO congestion management markets. The integration of the local short-term markets with the existing markets is an open task outside the scope of the Spanish demonstrator. However, the potential connection of the local markets demonstrated in the Spanish OneNet demonstrator is theoretically investigated in OneNet Tasks 3.3 [14] and with more details in section 5.2.

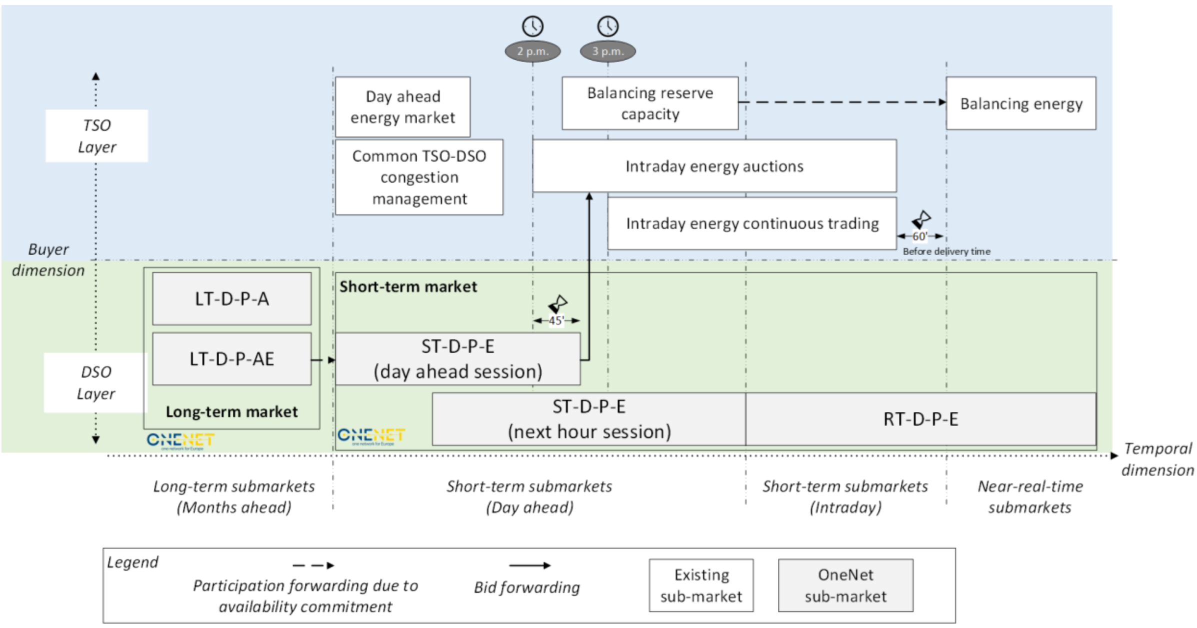

Figure 5.7: Overview of the Market Architecture for the OneNet Spanish demonstrator

In Appendix, Table 9.7, Table 9.8, Table 9.9, Table 9.10, and Table 9.11 describes the long-term and short-term markets designed for the OneNet Spanish demonstrator using the updated Theoretical Market Framework pillars and features described in section 5.1.

Polish demonstrator

The primary objective of the Polish demonstrator is to empower resources connected to the distribution level in supporting the operational needs of both the DSO and TSO. In line with market-based coordination, a digital platform has been developed and tested to procure services for balancing, congestion management, and voltage control. Figure 5.8 represents the schema representing the market architecture implemented by the Polish demonstrator. In Appendix, Table 9.12, Table 9.13, Table 9.14, Table 9.15, and Table 9.16 provide the detailed description of the Polish demonstrator's market architecture according to the TMF features.

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The activities of the Polish demonstrator centre around facilitating the provision of system services to both TSO and DSO through distributed resources. These services include balancing, congestion management, and voltage regulation [38], [41]–[43].

The Polish market architecture is characterised by a decentralised optimisation with sequential strategy with the forwarding of bids from local to national market with priority to DSO for flexibility allocation [38], [41]–[43]. The multi-level market architecture designed by the Polish demonstrator is characterised by a procedure that allow to allocate the DERs participating in the local market to the central TSO market for balancing by also granting priority access to DER-SPs for the DSO. Bid forwarding considers aggregation with grid constraint check. The local market (DA-D-P-E) has priority for flexibility allocation, bids may be forwarded to the national level (DA-TD-P-AE) to be used for TSO balancing service. Day-ahead operational procedures with specific auction mechanisms for congestion management and voltage control are considered.

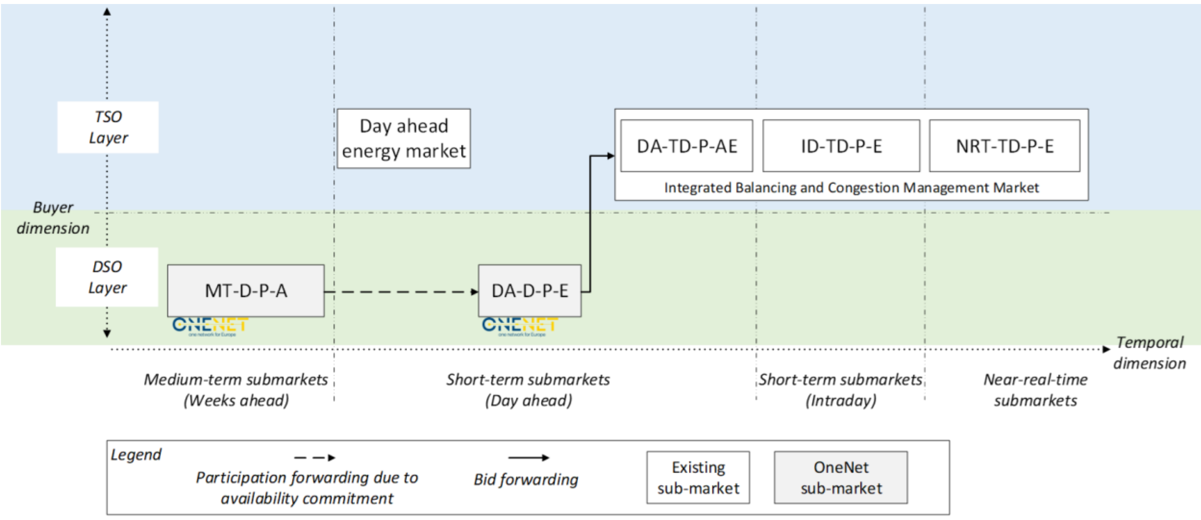

Figure 5.8: Overview of the Market Architecture for the OneNet Polish demonstrator, adapted from [16]

The local market includes a network constraint check procedure with detailed representation of DSO grid; hence, forwarded bids undergo aggregation considering DSO grid constraints. The leftover bids in the DSO local markets are forwarded to the TSO market in aggregated form by means of a procedure that considers the network topology and the compliance with the DSO network constraints. The aggregation process occurs through the utilisation of the flexibility platform in the day-ahead. The aggregated bid forwarded depends on the forecasted requirements from both the DSO and TSO. A DSO grid qualification process is addressed to ensure that the activation of DERs does not jeopardise the DSO network's operation by violating distribution network constraints. The aggregated forwarded bids offer an equivalent balancing offer at the TSO-DSO coupling point. This offer encompassing SPs within the DSO network comply with DSO network restrictions, ensuring the security of the DSO network since in the Integrated Balancing market, system services cannot be procured from DERs that may pose a risk to the DSO network.

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Czech demonstrator

The Czech demo key objectives o in terms of market design include the establishment of market mechanisms and TSO-DSO cooperation, analysis, and determination of solutions for addressing grid issues through the procurement of non-frequency grid services, and the testing of active customer involvement through aggregators (Small DER, DSR, BESS, EV) [41]–[43]. In Appendix, Table 9.17, Table 9.18, Table 9.19, Table 9.20, Table 9.21 describe the market architecture of the Czech demonstrator according to the updated TMF presented in this document. Figure 5.9 represents the schema of the market architecture implemented by the Czech demonstrator.

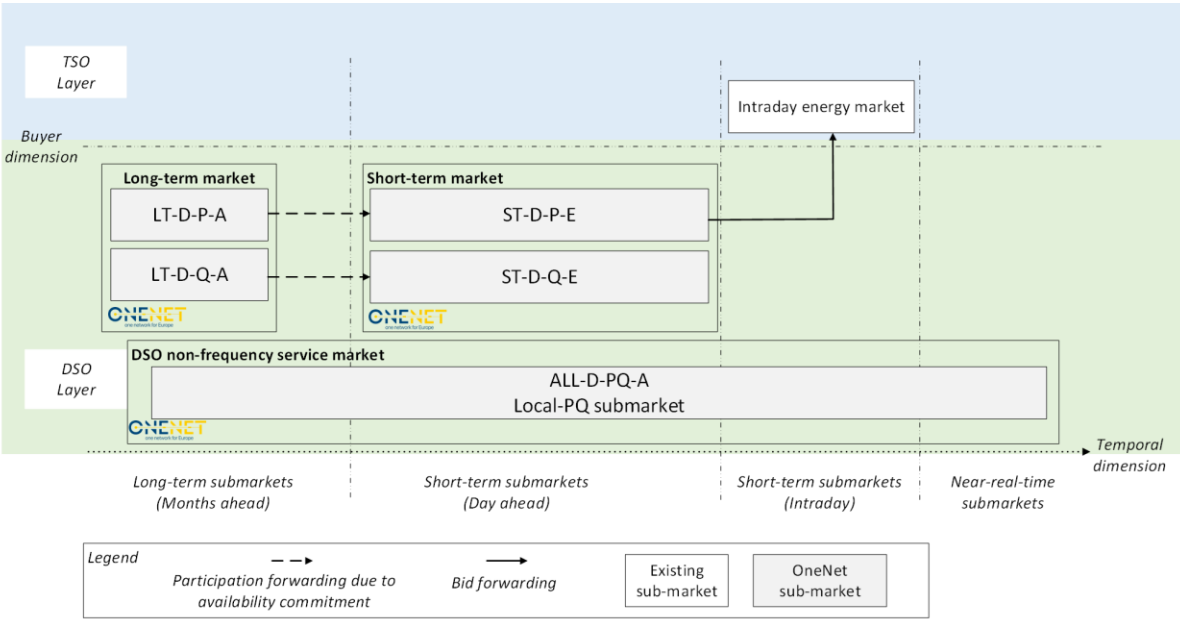

Figure 5.9: Overview of the Market Architecture for the OneNet Czech demonstrator

Presently, there is no regular marketplace for non-frequency flexibility services, and relevant services are typically contracted on a bilateral basis or provided as mandatory support [41]–[43]. Efforts are underway to address this by updating Czech grid codes, and selected aspects of these updates are being tested in the Czech demo through the Trading module of the Non-frequency Ancillary Services platform [41]–[43].

The Czech demo aims to test non-frequency services, such as voltage control through reactive power management and nodal area load management. The market platform developed by the Czech Republic demonstrator focuses exclusively on non-frequency services for the DSO, with the TSO not participating in the market processes. In the Local-PQ submarket (ALL-D-PQ-A), the DSO can procure non-frequency grid services from SPs connected at the distribution level [38], [41]–[43]. The non-frequency grid services procured involve both active and reactive power availability, and the procurement process includes both long-term and short-term products exchanged on the market platform. These services are not widely used on a market basis at present and are mostly operated bilaterally. A short-term and a long-term submarket for active and reactive power (availability and activation product types) have been considered in the Czech demonstration. Voltage

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control services focuses on protecting the High Voltage (HV) and Medium Voltage (MV) network. The Czech demo plans to use both active and reactive power management for voltage regulation, predictive activities for network congestions and voltage issues concern mainly the short-term of network operation. DSO Congestion management is based on active power management emphasising the use of predictive services and innovative solutions like active power management of EV charging stations and reactive power management for voltage regulation.

Hungarian demonstrator

The Hungarian market architecture comprises a local long-term submarket (WA-PQ-A) and a short-term submarket (DA-D-PQ-E), facilitating the exchange of both active and reactive power products with the primary goal of the market to address DSO service needs [38], [41]–[43]. In the long-term local submarket (WA-D-PQ-A-E), the DSO procures flexibility (availability and/or activation) from SPs to address local needs. Availability procurement is planned on a weekly basis. In the short-term market (DA-D-PQ-E), the DSO procures active and reactive power for day-ahead activation on a daily basis [38], [41]–[43]. Table 9.22,

Table 9.23, Table 9.24, Table 9.25, Table 9.26 describe the market architecture of the Hungarian demonstrator according to the updated TMF presented in this document. Figure 5.10 presents the schema the market architecture implemented by the Czech demonstrator [23].

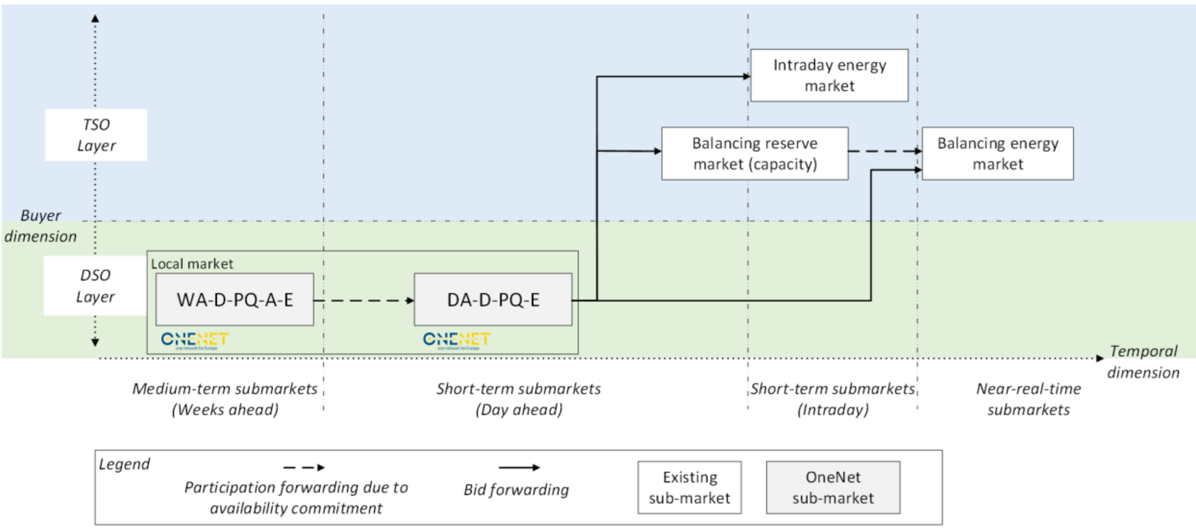

Figure 5.10: Overview of the Market Architecture for the OneNet Hungarian demonstrator

In the Hungarian demonstrator theoretical connections can be drawn between the OneNet submarkets and the existing submarkets: unaccepted bids in the OneNet local market can be aggregated and forwarded to the TSO markets [38], [41]–[43].

In the Hungarian demonstrator, the Long-Term submarket (WA-PQ-A-E) and Short-Term submarket (DA-D-PQ-E) exhibit explicit interaction concerning the commitment to participate in the activation submarket. However, SPs cleared in the long-term availability market are not obligated to participate in the short-term

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market. Nonetheless, the short-term activation market remains open to the participation of new SPs, including those not cleared in the long-term availability market.

The coordinated auction model incorporates a complex merit order list requiring an elaborate mathematical model. Consequently, only auction-typed markets enable the utilisation of optimisation models. Both active power (P) and reactive power (Q) solutions are suitable for addressing DSO congestions, each with different sensitivity factors.

All technically eligible SPs, whether stand-alone or aggregated, can participate as market players. This market is DSO-specific. Location-specific prices are deemed necessary, and the market operates on a framework of single-week auctions alongside week-ahead procurement. This choice is motivated by the complexity of the auction needed to price the coordinated auction effectively.

The DSO defines congestion zones and maintains a simplified grid topology based on the specific granularity needed, especially when dealing with multiple flexible providers exhibiting distinct sensitivity factors. The determination of congestion zones is contingent on the DSO's definition, influenced by factors such as scheduled line outages confirmed by the TSO around the same period as the week-ahead gate opening. This information is integrated into network calculations, providing a list of network constraints and delineating the group of bidders capable of resolving specific congestions.

Northern cluster demonstrators

The Northern demonstrator adopts a common TSO–DSO market architecture, where both entities act as buyers across all sub-markets [44]–[48]. This approach is visually represented in Figure 5.11, showcasing the market architecture of the OneNet demonstrator. The sub-markets within the Northern demonstrator's architecture cover procurement from long-term to near-real-time, allowing all resources connected to the transmission and distribution grid to participate. In Appendix, Table 9.27, Table 9.28,

Table 9.29, Table 9.30, Table 9.31 provide the detailed description of the Northern demonstrators' market architecture according to the TMF features.

The LT-TD-P-AE submarket, focusing on the long term, involves resources submitting active power availability bids (capacity) with corresponding active power activation prices (energy). The DA-TD-P-A is a day-ahead sub-market centred on the active power availability product. On the other hand, ID-TD-P-E and NRT-TD-P-E are intraday and near-real-time sub-markets dealing with active power activation products. Availability product sub-markets determine the forwarding of cleared bids to related activation product sub-markets. Additionally, bid forwarding occurs between the intraday energy market (ID-TD-P-E) and the NRT-TD-P-E sub-markets.

The common TSO–DSO market architecture in the Northern demonstrator is characterised by service-agnostic products for congestion management and frequency control, encompassing both active power activation and availability products. Flexibility allocation occurs through centralised market optimisation, with no priority given to TSO or DSO. Bids from intraday energy markets can be forwarded to other markets,

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contingent upon inclusion of locational information and adherence to grid constraints. Bid sharing between the intraday energy market and other sub-markets is permitted under uniqueness conditions. Bids with locational information undergo compliance checks for grid constraints, and all bid forwarding and selection processes ensure bid uniqueness among sub-markets to prevent double clearing.

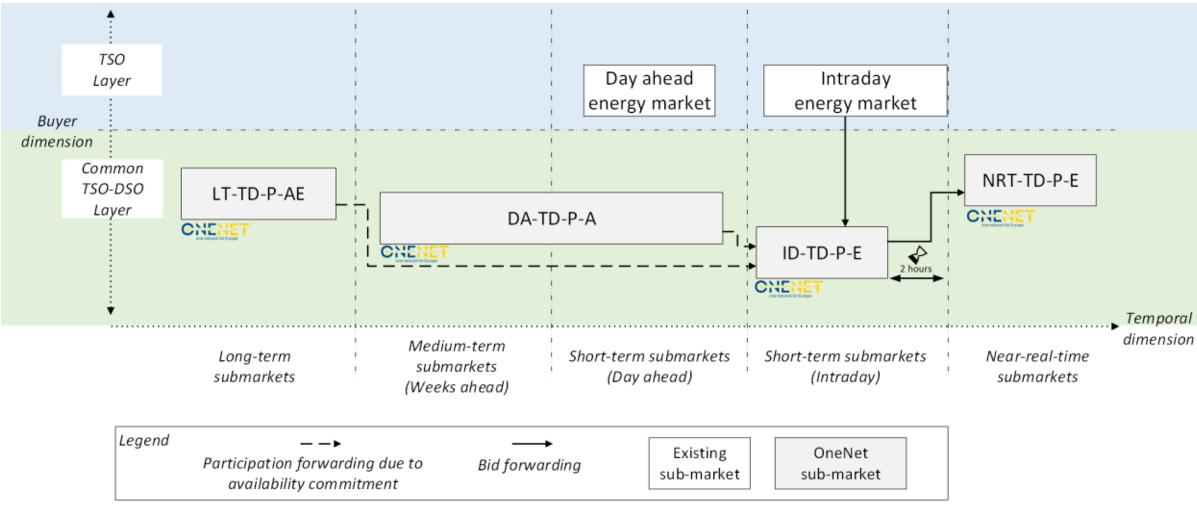

Figure 5.11: Overview of the Market Architecture for the Northern demonstrators, adapted from [16]

In all sub-market, both balancing and congestion management will be considered. The optimisation method developed for selecting bids in Northern cluster considered both congestion and balancing together. It will accept as an input the range of acceptable unbalancing tolerance after congestion management. It could be zero, which means that the congestion management must not create a new imbalance; or could be infinite meaning that imbalance effects are neglected. In the LT-TD-P-AE submarkets the bids include both availability and energy price, and selection (i.e., optimisation) will happen according to the expected duration if activation, is already announced in the call for tender. Hence, remuneration considers both availability and energy. The SPs are selected in long term in advance for availability but SO (usually DSO) can request activation in the day ahead bases. SP will get the activation fee according to the real activation time and the price already announced in long-term submarket.

SPs awarded in long-term or short-term capacity market are obliged to bid in related energy market (e.g. short-term energy market, near-real-time energy market). However, free bids are always allowed in energy markets. In ID-TD-P-E submarket, the bid is selected from the Intraday market and follows its rule pay-as-bid. Regarding NRT-TD-P-E market further debates are needed whether to favour pay-as bid or pay-as-clear rule.

Grid data concerns up to level of resource aggregation, resources can be aggregated at the lowest node level which has been reported by the SO as part of grid data (SO calculates and shares the sensitivity PTDF matrix used in the bid optimisation process). The bid selection is based on optimisation (auction) in TSO & DSO Coordination Platform (T&D CP) and the results are transferred to MO that is in charge of informing all related

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parties including SOs and SPs. SPs activation is addressed through the MO. TSO has access to DERs if they can buy and activate flexibility from DERs, the T&D coordination platform plays as the middleman on behalf of both TSO and DSO.

In the Northern demonstrators, a form of bid sharing across submarkets is formalised. Nord Pool Intraday market corporates with the Northern Demonstrator platform to use the available intraday bids (with locational tags) as input for congestion in both transmission and distribution systems. There is no gate closure time in the intraday market, but according to the pre-agreement, e.g., 1 or 2 hours before the delivery time (of the ID-TD-P-E submarket) the intraday market sends all the available bids to the OneNet platform (this is the virtual gate closure). The ID-TD-P-E submarket optimise and clears the markets, the selected bids are deleted from the intraday market. Mitigation measures are under discussion to prevent that a bid is simultaneously cleared in both markets (e.g. in the intraday that make it not available for the ID-TD-P-E). After ID-TD-P-E gate closure the unused bids can be forwarded to NRT-TD-P-E market.

5.2 Bid Forwarding Analysis for the OneNet demonstrators

In this section, the analysis of the bid forwarding potential between different OneNet local markets and central electricity markets is presented. As explained in the methodology in section 2.2, the TMF description of the OneNet demonstrators' market design presented in section 5.1.6 is used to identify pairs of markets that show potential for higher coordination. Unless otherwise stated, the first market denotes the first market in the sequence, i.e., the market from which the uncleared bids are forwarded, and the second market denotes the market to which the uncleared bids from the first market are forwarded.

Case 1. Poland local CM capacity to RR markets

The market design features of the Polish local CM market and RR markets are presented in Table 5.2.

First market: Medium-term local congestion management capacity markets

Second market: Replacement reserves market

Table 5.2: The market design features of Polish local CM energy and Polish RR markets

Market design feature	Polish local CM capacity market	Polish replacement reserves market [49]
Allowed technologies	All technologies allowed	Generation, storage and demand
Aggregation	Aggregation allowed	Aggregation not allowed
Market time unit (MTU)	15 min	1 hour
Locational granularity	Local distribution	Nodal
Gate Closure Time	Weeks-ahead	Day-ahead
Type of product	Capacity	Capacity

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Technical requirements	FAT below 16 h	FAT – 30 min, ramping period – maximum 30 min, preparation period – maximum 30 min, other standard RR product requirements
Bid structure	Simple	Unit-based bids, complex bids allowed
Minimum bid size	1 kW	1 MW

Description: The Polish local congestion management market for capacity is used to procure necessary availability products weeks in advance. These products are procured at local distribution level and has a minimum bid size of 1 kW. The demo has a focus on enabling the resources connected at the local level to support system operation at both DSO and TSO levels [38].

The Polish balancing markets use Frequency Containment Reserves (FCR), automatic Frequency Restoration Reserves (aFRR) and Replacement Reserves (RR) [50]. In FCR and aFRR markets, only generators are allowed to participate whereas in RR can be provided by generation, storage and demand. However, the Polish TSO is currently developing new schemes to allow storage, demand response, renewables and aggregators in the market [51, p. 20]. Poland is a central-dispatching system and has stricter requirements regarding the participation in the balancing market than a self-dispatch system [4]. A constraint that is brought forth due to this form of dispatch is the unit-based bidding. The balancing bids made to the market must be assigned to a specific scheduling unit [50]. Similarly, the imbalances are calculated at the scheduling unit level rather than at the scheduling group level. The Polish balancing markets are undergoing a reform and some of the barriers presented to aggregation is expected to be removed [51].

Analysis: The technical requirements for the participation in the RR markets are higher than that of the congestion management markets. Starting from the full activation time (FAT), the range of values allowed in the local market (< 16h) is much higher than the range allowed in the RR markets (FAT < 30 min). This implies that only few bids from the CM market would be eligible for use in the RR markets. Additionally, the minimum bid size of the local markets is 1000 times smaller than the one of RR, necessitating the need of an aggregation stage. However, the current balancing market rules in Poland does not allow aggregation of resources in the market, which makes it impossible for the small-sized SPs to participate in this market. The unit-based bidding also creates a barrier for the participation of aggregated SPs in the market. Therefore, implementation of a bid forwarding process between the Polish CM capacity and RR capacity markets is not very practical due to the high number of unfavourable conditions. Nevertheless, it is important to note that a balancing market reform is underway and some of these barriers may be removed in the near future.

Case 2. Czech Republic local capacity to intraday markets

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The market design features of Czech local CM capacity and Czech intraday markets are presented in Table 5.3.

First market: Medium-term local congestion management market for capacity

Second market: Intraday markets

Table 5.3: The market design features of Czech local CM capacity and Czech intraday markets

Market design feature	Czech local CM capacity market	Czech intraday markets
Allowed technologies	All technologies allowed	All technologies allowed
Aggregation	Allowed	Allowed
Market time unit (MTU)	Hourly	Hourly
Locational granularity	Local distribution	Zonal
Gate Closure Time	Weeks-ahead	1 hour before delivery
Type of product	Capacity	Energy
Technical requirements	FAT less than 5 min	No specific requirements
Bid structure	Simple	Complexities allowed
Minimum bid size	1 kW	100 kW

Description: The Czech demo offers only non-frequency services for the DSO which includes active and reactive power availability [38]. In this analysis, we only consider the active capacity market.

The Czech intraday markets are a apart of the Single Intraday Coupling (SIDC) project that uses a continuous trading model [52]. The market opens at 15:00 the day before the delivery and closes one hour before the trading period. The market is operated by OTE (i.e., the Czech electricity and gas market operator).

Analysis: Generally, intraday markets have lower entry barriers and lenient participation conditions than balancing markets or even congestion management markets. Hence, from the product and participation perspective, the bid forwarding possibility between a local CM market and intraday market is promising. A frequent barrier from the product side is the minimum bid size of the intraday markets. To overcome this barrier, an aggregation stage will be required.

In this particular case, the main barriers are the difference in the type of product and the market timing. The local CM market trades a capacity product (kW) whereas the intraday markets trade energy (kWh or MWh). When a capacity bid is cleared, the participant has a responsibility to make the cleared capacity available in the energy (or the activation) market of the same product. It implies that this capacity cannot be offered in other markets such as day-ahead or intraday. As a result, the capacity bid should ideally represent the opportunity cost of not offering the reserved capacity in other markets and the energy bid should represent the marginal cost of producing a unit of energy (assuming auction-based clearing). Therefore, the price of capacity would be very different from the price of energy for the same asset. When bid forwarding is considered between capacity and energy markets, there should be a separate representation of capacity and energy prices.

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The second main barrier is related to the market timing. The Czech CM capacity market takes place weeks-ahead of the delivery while the intraday markets only open the day before delivery at 15:00. It is unclear whether the bid forwarding responsible can hold on to the bids for such a long period of time. Additionally, the Czech intraday markets use a continuous trading model where the optimal bid price may not be the representation of marginal production cost. In an auction system, the market players are guaranteed to gain inframarginal profits if they are not the marginal generator. However, in a continuous trading system using a pay-as-bid pricing, the participants have to anticipate the market clearing price and mark-up their bids in order to gain a profit. The predictability of market clearing prices will be much higher closer to the intraday timeframe than weeks in advance. Hence, by setting the energy price weeks ahead, the participants may risk losing profits. A solution for this problem is to allow the participants to revise their bid values close to the intraday timeframe.

Case 3. Hungary local capacity to mFRR capacity markets

The market design features of the Hungarian local CM capacity and the Hungarian mFRR capacity markets are presented in Table 5.4.

First market: Local congestion management market for capacity

Second market: Manual Frequency Restoration Reserve (mFRR) markets for capacity

Table 5.4: The market design features of the Hungarian local CM capacity and the Hungarian mFRR capacity markets

Market design feature	Hungarian local CM capacity market	Hungarian mFRR capacity markets [50]
Allowed technologies	All technologies allowed	Storage not allowed
Aggregation	Allowed	Allowed temporarily
Market time unit (MTU)	Hourly	Hourly
Locational granularity	Distribution-level	Zonal
Gate Closure Time	Weeks-ahead	Months-ahead
Type of product	Capacity	Capacity
Technical requirements	No technical requirements	Prequalification required, full activation time = 12.5 min or 15 min
Bid structure	Step bid	Complex bids allowed
Minimum bid size	50 kW	1 MW

Description: The Hungarian demonstrator uses active and reactive products for voltage control and congestion management for distribution networks [38]. The DSO uses a long-term (weeks-ahead) local submarket to procure capacity and a short-term (daily) local market to procure active and reactive energy for activation.

The Hungarian balancing market is operated by the TSO, MAVIR [50]. The balancing capacity auctions are held month in advance. For each hour of the specific day, the TSO selects the balancing capacity based on the balancing capacity offers. Depending on the market clearing results, the BSPs who are awarded with the capacity

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bids have an obligation to keep their capacities available. The aggregators are allowed to participate in the balancing markets through a temporary scheme [50]. A permanent solution for integrating aggregators is expected by 2024.

Analysis: The mFRR markets have stricter technical requirements that are checked through a prequalification process. If only the prequalified bids are forwarded to the next stage (mFRR capacity markets), the issue of technical requirements compatibility could be solved. However, the main barrier in this case is the gate closure time of mFRR capacity markets. mFRR capacity is procured months in advance whereas local CM capacity is procured weeks-ahead. Hence, it is impossible to forward bids from local CM market to mFRR capacity markets. Theoretically, bids could be forwarded from the mFRR capacity markets to local CM market but, in this direction, the number of bids available for providing a local service will be very less. The Hungarian balancing markets are highly concentrated, which reduces the total pool available [53]. Additionally, the locational granularity of the local CM bids is set at distribution-level whereas the balancing is at zonal level. Hence, without additional granular locational information, the bids cannot be considered for local market clearing.

Case 4. Hungary local CM capacity to aFRR energy markets

The market design features of Hungarian local CM capacity and the Hungarian aFRR energy markets are given in Table 5.5.

First market: Local congestion management market for capacity

Second market: Automatic Frequency Restoration Reserve (aFRR) markets for energy

Table 5.5: The market design features of Hungarian local CM capacity and the Hungarian aFRR energy markets

Market design feature	Hungarian local CM capacity market	Hungarian aFRR energy markets
Allowed technologies	All technologies allowed	Storage not allowed Free bids allowed
Aggregation	Allowed	Allowed temporarily
Market time unit (MTU)	Hourly	Hourly
Locational granularity	Distribution-level	Zonal
Gate Closure Time	Weeks-ahead	1 hour before delivery
Type of product	Capacity	Energy
Technical requirements	No technical requirements	Prequalification required, FAT of 15 min
Bid structure	Step bid	Complex bids allowed
Minimum bid size	50 kW	1 MW

Description: As mentioned in Case 4, the Hungarian local CM capacity market is used to procure capacity for short-term congestion management energy activations.

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The Hungarian aFRR energy markets is operated by the TSO, MAVIR. Although the prequalification requirements are high, like other balancing markets, these markets allow free bidding. Hence, any qualified BSP can submit balancing energy bid in the market. The bids have an hourly resolution but the settlement is done at a quarter-hourly basis [50].

Analysis: The aFRR markets have stricter participation requirements than the local CM market. Therefore, only prequalified bids can be forwarded to the aFRR markets. The minimum bid size of the Hungarian aFRR markets is much higher than that of the local markets, requiring an intermediate bid aggregation stage. It should be noted that aggregation is allowed in Hungarian market in a temporary basis. The regulatory uncertainties regarding these crucial aspects will limit the potential for implementing market coordination schemes.

Apart from the participation factors, the major barrier in this case is the difference in the product type. The local CM product is a capacity product whereas the aFRR activation is an energy product. As discussed in Case 3, the local CM bids should carry an energy price component or allow the market players to revise the prices before forwarding the bids. In Case 3 (Czech local to intraday), the forwarded market has a pay-as-bid system where the market players have to mark-up their bids. However, in this case, the market uses a marginal pricing system, which allows the market players to show their true marginal costs within the bid. Therefore, using some intermediate bid processing stage, bid forwarding is possible in this system.

Case 5. Spanish local CM energy market to intraday markets

The market design features of Spanish local CM energy and the Spanish intraday markets are given in Table 5.6.

First market: Local congestion management market for energy

Second market: Intraday auction markets

Table 5.6: The market design features of Spanish local CM energy and the Spanish intraday markets

Market design feature	Spanish local CM energy market	Spanish intraday markets
Allowed technologies	All technologies allowed	All technologies allowed
Aggregation	Allowed. Upward and downward flexibility cannot be aggregated in the same bid	Allowed. Generation and demand cannot be aggregated in the same bid
Market time unit (MTU)	Hourly (15 min in the near future)	Hourly (15 min in the near future)
Locational granularity	Nodal	Zonal
Gate Closure Time	Day-ahead (14:45)	Intraday (15:00, 17:50, 21:50, 01:50, 04:50, 09:50)
Type of product	Energy	Energy
Technical requirements	FAT < 1 hour	No specific requirements
Bid structure	Simple	Complex bids allowed
Minimum bid size	10 kW	100 kW

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Description: The Spanish local congestion management market is used to procure local resources for solving congestion at distribution-level. These markets are linked to the local CM capacity markets as the cleared SPs in the capacity markets have an obligation to submit energy bids in the local CM energy markets.

The Spanish intraday markets consists of six discrete intraday auction sessions and a continuous trading market [54]. In this analysis, we consider only the intraday auction markets. These markets are operated by OMIE, the Iberian nominated electricity market operator (NEMO) for Spain and Portugal. As it is an intraday market for flexibility, there are no strict technical requirements for participation. The minimum bid size (100 kW) is lesser than the balancing markets where generally the minimum bid size is 1 MW.

Analysis: The intraday markets are good candidates for implementing bid forwarding as some products are similar to the ones negotiated in the local CM markets. While intraday markets trade flexibility at a national or zonal level, the local markets trade the same at distribution level. Correspondingly, small variations can be seen in the product requirements such as the level of locational granularity in the bid and minimum bid size. However, these differences do not prevent the bid forwarding process. With an aggregation stage, the uncleared local bids can be aggregated and sent to the intraday markets at the condition that the aggregation follows the aggregation rules set for intraday markets. Even though the timing of the local market clearing and intraday first auction sessions are constraining (local closes at 14:45 and intraday first auction at 15:00), the subsequent sessions of the intraday markets (17:50) can be used for trading also the 24 hours from day-ahead as in first auction (15:00). Considering these factors, Spanish local – intraday markets show the highest potential for bid forwarding. Another possibility for the Spanish case is to forward the bids further into the continuous intraday markets, as discussed in [13].

Case 6. Finnish local energy to mFRR markets

Table 5.7 compares the market design features of the OneNet TSO-DSO CM and mFRR markets in Finland.

First market: OneNet TSO-DSO congestion management markets for energy

Second market: mFRR energy markets

Table 5.7: Market design features of the OneNet TSO-DSO CM and mFRR markets in Finland

Market design feature	Northern OneNet TSO-DSO CM market	mFRR markets
Allowed technologies	All technologies allowed	Generation, consumption and storage
Aggregation	No restriction applied	Aggregation within the same transmission area and aggregated resources must be under the responsibility of the same BRP
Market time unit (MTU)	1 hour	1 hour (15 min products will be used after the first quarter of 2023)
Locational granularity	Nodal	Transmission area

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Gate Closure Time	2 hours before delivery	45 minutes before delivery (25 minutes after MARI connection)
Type of product	Energy	Energy (capacity reservation not obligatory)
Technical requirements	Technical prequalification required. FAT = 2 hours, manual activation	Technical prequalification required. FAT = 15 min (12.5 min after MARI implementation), manual activation
Bid structure	Non-symmetric and non-divisible products permitted	Non-symmetric bids allowed, complex bids supported by MARI will be allowed from Q4 of 2024
Minimum bid size	0.1 MW	5 MW (1 MW after MARI integration)

Description: Finland is part of the Northern cluster of the OneNet project with Estonia, Latvia, and Lithuania. The proposed submarkets trade active and reactive products (capacity and energy) for system services such as frequency control, voltage control, and congestion management [38]. In this analysis, we check the bid forwarding potential of a short-term congestion management market for DSO and TSO grids to mFRR markets.

In Nordic countries, manual frequency restoration reserve (mFRR) energy is procured in a common regulating power market (RPM). RPM will be replaced by the mFRR Activation Energy Market (mFRR EAM), which will act as an intermediary for the MARI platform [18] Due to the integration project, changes in certain product attributes and market design elements in the Finnish mFRR market are expected. A major change in the mFRR bid requirements is the minimum bid size (from 5 MW to 1 MW). Among the market design features, GCT will change from 45 to 25 minutes before delivery and MTU from 60 to 15 minutes.

The Finnish balancing market is divided into two transmission areas, North and South [55]. Aggregation is permitted for resources located within the same transmission area. However, an exception has been made for small market players. Resources located in two transmission areas can be aggregated if aggregation is required to meet the minimum bid size. Still, due to system security concerns, an aggregated bid from two transmission areas might not be used in all situations.

Analysis: The market design features such as gate closure time, locational granularity, and bid structure are favourable for bid forwarding between these markets. Regarding the type of product, the mFRR market allows the participation of free bids, i.e., participation of balancing energy bids without obligation to participate in balancing capacity markets. Hence, bids from local markets can be forwarded without a contractual obligation from the balancing capacity market. The main challenges, in this case, are posed by the product requirements. Compared to energy market products, balancing products require specific technical attributes that allow the TSOs to balance the system in a short time. Hence, the first filter for the participation of resources from local markets is prequalification; only bids from prequalified units can be forwarded to mFRR markets. Once the non-eligible bids are filtered out, the next process is aggregation. According to the market rules, aggregation must be done at the transmission area level, and the aggregated bid should have a minimum capacity of 5 MW (or 1 MW in the near future). Currently, Finnish markets are transitioning from 60 minutes products to 15 min products. During this transition period, the TSO converts 60 min products into four identical products of 15 min.

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After this phase, hourly products from local flexibility markets must be converted to 15 min products. Accounting for all these conditions, bid forwarding, in this case, can be considered conditional bid forwarding.

5.3 Key remarks on market harmonisation through bid forwarding analysis

The summary of results of the bid forwarding analysis is given in Table 5.8, where the bid forwarding potential is marked as 'not possible', the main barrier contributing to it is highlighted in red. The bid forwarding potential of the markets are classified as favourable and unfavourable. In all analysed cases, there are barriers that prohibit a direct forwarding of bids from one market to the next. However, in cases marked as favourable, some intermediate bid processing stage could be designed to address this barrier and forward the bids. In Case 2 (Czech local CM capacity to intraday), the bid processing stage should aggregate the bids and allow the participants to revise their bid prices. Figure 5.12 shows the simplified representation of bid forwarding between Czech local CM markets for capacity and Czech intraday markets. Similarly, in Case 5 (Spanish local CM energy to intraday), the bid processing stage should disaggregate the bids and reaggregate the bids based on the rules of the intraday markets, as shown in Figure 5.13. Notably, intraday markets have the least resistance to bid forwarding processes. Hence, as a test case, bid forwarding could be considered between local flexibility markets and intraday markets of the same country.

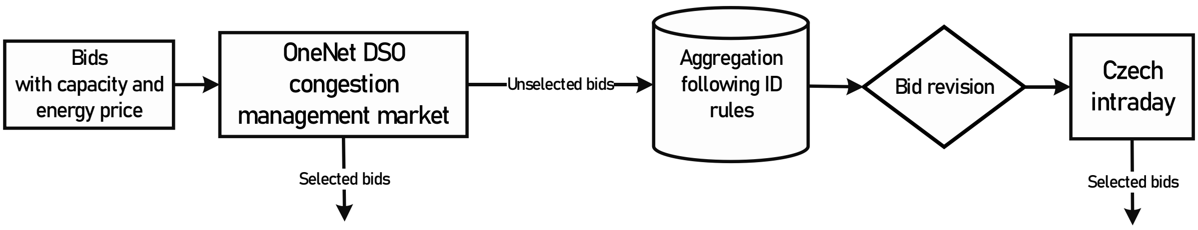

Figure 5.12: Simplified representation of bid forwarding between Czech local CM markets for capacity and Czech intraday markets

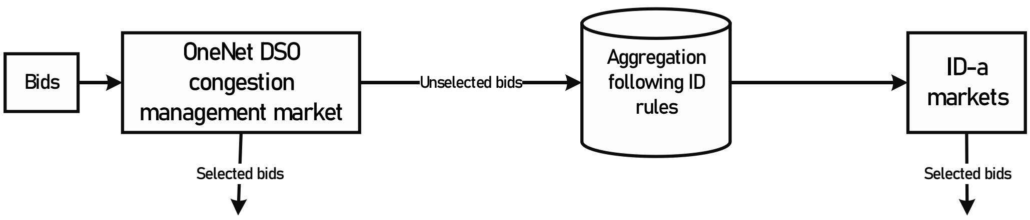

Figure 5.13: Simplified representation of bid forwarding between Spanish local CM market for energy and Spanish intraday auction markets

Another potential candidate for bid forwarding is Finnish local CM energy to mFRR energy markets. Only bids that are prequalified for use in mFRR markets can be forwarded from local CM market to the balancing market. Apart from that, the bid processing stage includes MTU conversion and bid aggregation. Although the number of stages in bid processing is not high, the definition of the prequalification conditions could reduce the volume of bids forwarded to the next market. If prequalification is not allowed at a portfolio or group-level, then it is

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challenging for the aggregated bids to participate in the balancing market. Similarly, the ease at which prequalified groups can be redefined (through addition or removal of some units) will also indirectly determine the ease at which uncleared bids can be aggregated. Hence, if prequalification conditions are not very strict, the bids can be easily forwarded from local to balancing markets.

On the other hand, the cases marked as unfavourable has regulatory conditions that explicitly prevent the forwarding of bids from one market to another or significantly reduce the number of bids that could be forwarded. In Case 2 (Poland local CM to aFRR energy) and Case 5 (Hungary local CM to aFRR energy), the main restriction is related to free bidding. Only participants who are awarded capacity in the balancing capacity market can participate in the balancing energy market. The participants who have cleared bids in the balancing capacity market has an obligation to make this capacity available for the balancing energy markets. Hence, this capacity will not be offered in other markets such as local markets or intraday. As a result, it is impractical to have a bid forwarding scheme between a local market and a balancing energy market which does not allow free bidding.

Case 1 (Hungary local CM to RR capacity) is unfavourable due to the restriction on aggregation. The minimum bid size of a local market is almost always less than that of the RR capacity market. Hence, aggregation is a necessary precondition for bid forwarding between those markets. Countries like Poland, using central-dispatching model in the balancing market, requires granular locational data to schedule and dispatch the units [4]. Aggregating different resources could be an issue for such systems as the precise location of the units will not be known. Nevertheless, central-dispatching systems have started to allow aggregation through pilot programmes (e.g., the Italian case) [4]. Even in the Hungarian markets, the aggregators are permitted temporarily in the aFRR and mFRR markets [50]. Yet, regulatory uncertainties can affect the potential for implementing market coordination techniques. Hence, permanent solutions to aggregations in such centralised systems is necessary for the adoption of bid forwarding processes.

Unlike the above cases where the regulation of the second market prevents bid forwarding, Case 3 (Hungary local CM capacity to aFRR energy) is challenged by the design of the first market. The local market (local CM capacity) takes place after the central market (mFRR capacity) and hence, bid forwarding is not possible in the direction of local to central market. The other direction can be implemented if the locational data is available within the bid. This is similar to the usage of mFRR bids for managing congestion in the transmission network. However, the quantity required to resolve a local need will be much lesser than that of a transmission grid need. It might be more profitable for a prequalified unit to offer their capacities in other balancing reserves market or in balancing energy markets, as their prices tend to be high. Hence, without sufficient financial incentives, it is uncertain whether there would be enough quantity of bids from central to local markets.

Finally, in those cases where the forwarding of bids from the local to the central market is allowed, in order to ensure that the activation of the resources associated with the forwarded bids does not cause problems for

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the connecting SO network, it is essential to adopt the necessary technical procedures to check the network constraints. The solutions designed and demonstrated in OneNet (i.e. centralised as described in section 0, decentralised as described in section 0) are equally valid and can be adopted depending on the characteristics of the market architecture.

Finally, in the cases in which bid forwarding from local to central market is allowed, with the aim to ensure that the activation of the resources related to the forwarded bids do not cause problems to the connecting SO network, it is fundamental to adopt the necessary technical procedures to check grid constraints. The solutions designed and demonstrated in OneNet (i.e., centralised and decentralised) results equally valid and can be adopted depending on the characteristics of the market architecture.

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Table 5.8: The summary of bid forwarding analysis.

When the bid forwarding potential is marked as 'not possible', the main barrier contributing to it is highlighted in red.

Analysed case	Current bid forwarding potential	Identified barriers	Solutions to the identified barriers
Case 1: Hungary M1 – local CM capacity M2 – RR capacity	Unfavourable	Aggregation not allowed in M2	Allow aggregation in the balancing market
		Technical requirements of M2 much stricter than M1	Filter the bids that are prequalified for M2 before forwarding the bids to M2
		Change in the MTUs between markets	Convert the MTUs from 15 min to 1 hour through a predefined mechanism
		Minimum bid size of M1 is very low compared to M2	Allow aggregation to meet the bid size requirements
		Aggregation not allowed	Allow aggregation in the balancing market
		Change in MTUs between markets	Convert the MTUs from 15 min to 1 hour through a predefined mechanism
		Technical requirements of M2 are much stricter than M1	Filter the bids that are prequalified for M2 before forwarding the bids to M2
		Minimum bid size of M1 is very low compared to M2	Allow aggregation to meet the bid size requirements
Case 2: Czech Republic M1 – local CM capacity M2 – Czech intraday	Favourable	The GCT of M1 is weeks-ahead whereas the intraday markets are one hour before delivery	The market players should be given the option to revise the bid quantity and prices before sending them to M2
		The type of product is different	The bids should carry a capacity price and energy price. Also, the participants should be allowed to revise the prices close to real-time
		The minimum bid size of M1 is lower than that of M2	The bids must be aggregated before forwarding them to M2
Case 3: Hungary M1 – local CM capacity M2 – mFRR capacity market	Unfavourable	The GCT of M2 is months-ahead whereas GCT of M1 is weeks-ahead	The local market timings should be set considering the central market timings
		Storage is not allowed	Filter out the bids belonging to storage
		Technical requirements of M2 are stricter than that of M1	Filter the bids that are prequalified for M2 before forwarding the bids to M2
		The minimum bid size of M1 is lower than that of M2	The bids must be aggregated before forwarding them to M2
Case 4: Hungary M1 – local CM capacity M2 – aFRR energy market	Unfavourable	Storage is not allowed to participate. Free bidding is not allowed in M2	Allow the participation of all technologies and remove the restriction on free bidding
		Type of product is different	The bid to M1 should contain a price for energy (that could be updated close to the real-time)
		Technical requirements of M2 are stricter than that of M1	Filter the bids that are prequalified for M2 before forwarding the bids of M2
		The minimum bid size of M2 is higher than that of M1	The bids must be aggregated before forwarding them to M2
Case 5: Spain M1 – local CM energy market M2 – intraday auction markets	Favourable	Aggregation conditions of M2 are different from M1	The aggregated bids from M1 should be disaggregated and reaggregated following the rules of M2
		The minimum bid size of M2 is lesser than that of M1	The bids must be aggregated before forwarding them to M2
Case 6: Finland M1 – local CM energy market M2 – mFRR markets	Favourable	Change in MTUs between markets	Convert the MTUs from 15 min to 1 hour through a predefined mechanism
		Technical requirements of M2 much stricter than M1	Filter the bids that are prequalified for M2 before forwarding the bids to M2
		The minimum bid size of M2 is higher than that of M1	The bids must be aggregated before forwarding them to M2

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5.3.1 Policy recommendations

From the analysis of market architecture harmonisation potential, some major factors enabling the coordination between markets could be identified. Based on that, the main policy recommendations can be summarised as below:

1) **Aggregation should be permitted in all markets**. Certain balancing markets have restrictions on aggregation due to their centralised nature, but some exceptions should be made for distribution-connected resources (or at least the resources connected to a less constrained area of the grid).

    Allow free bidding in the balancing energy markets. The capacity reservation condition for balancing markets helps the TSOs to procure enough capacity in advance for the operational security. But limiting the pool of resources bidding into the balancing energy markets to the reserved capacities may increase the possibilities for gaming (a good discussion on this issue can be found in [56]).

2) **Design local markets taking the timing of the existing central (or wholesale) markets into consideration**. Wherever possible, the local markets should coordinate with the existing market in order to provide revenue stacking potential for the market players and to maximise the procurement efficiency of the markets. This means that the market timings should be fixed in a way that the uncleared bids from the local markets get a chance to participate in the wholesale markets.

3) **Increase the synergies between the local flexibility and intraday markets**. The intraday markets trade flexibility at central level (or transmission level). The minimum bid size and delivery period of the intraday markets are smaller compared to the other wholesale markets. Hence, these markets are good candidates for incorporating local resources into the central and wholesale energy markets.

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6 Market phases harmonisation assessment

6.1 Introduction

As described in section 2.3, market phases represent the necessary procedures to be undertaken to ensure the acquisition of flexibility services from third parties. Depending on the specific acquisition mechanism adopted (i.e. flexible access and connection agreements, dynamic network tariffs, flexibility market, bilateral contracts, cost-based mechanism, obligation) [3], the definition and sequence of market phases changes. In the context of the OneNet project, the market phases definition and sequence refer to markets (i.e., discrete auctions) for acquiring SO services. In this section, the outcome of the analysis of the solutions adopted by the OneNet demonstrators for the market phases are presented according to the methodology described in section 2.3.

6.2 Market phases identification

The objective of T11.2 is to assess the potential for harmonisation in the demonstrator solutions. Therefore, the analysis of market phases in T11.2 is limited to a relevant subset demonstrated by a representative set of OneNet demonstrators. The selection of the market phases of interest is based on the analysis of BUCs and the result of direct interactions with demonstrators' partners considering the OneNet project objectives and the ongoing regulatory trending topics [15], [34]. Among the market phases described in section 2.3, three phases are selected to be further investigated in the T11.2 activities: technical prequalification, baselining, and procurement. Figure 6.1[4] shows the adoption of those market phases by the OneNet demonstrators.

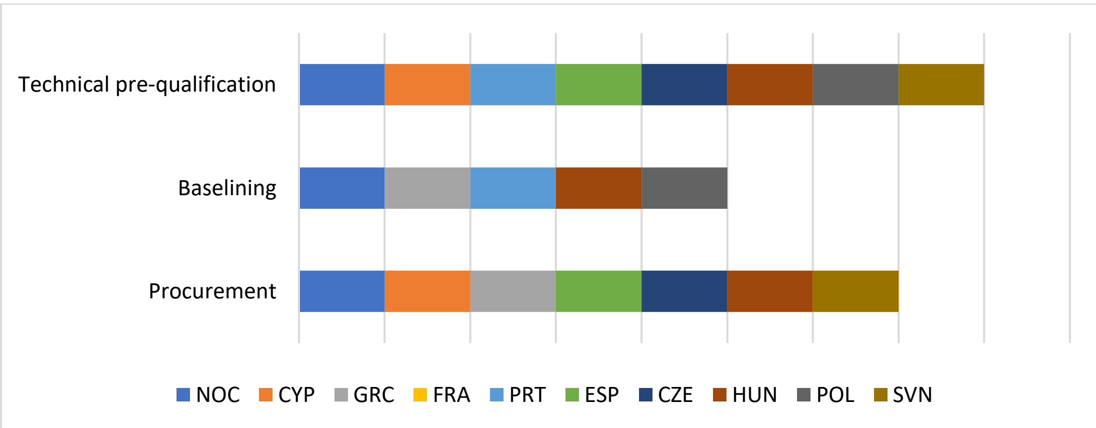

Figure 6.1: Market Phases considered for demonstration by the OneNet demonstrators

[4] Figure 6.1 uses ISO 3166-1 alpha-3 three-letter country codes for all demonstrator countries except for the Northern Cluster that is represented as "NOC".

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Prequalification, as defined in [15]: “ex-ante prequalification means the ex-ante process to verify the compliance of a potential service provider with the technical requirements set by the SO for the provision of a SO product (product prequalification) and where applicable, the process to verify the ability of the grid to technically accept the delivery of such a product (grid prequalification). In the product prequalification the SO may require the potential service provider to pass an activation test.

Baselining for system service provision, often referred to as flexibility baselining, is a method used to establish a reference or baseline level of electrical grid performance or output. It serves as a benchmark against which the contribution of flexible resources or services to the grid can be measured. In the context of system services, this involves quantifying the normal operating patterns or capabilities of energy resources, such as generation units or demand response assets. By establishing this baseline, grid operators and energy service providers can accurately assess the impact and value of flexibility services provided to the grid, such as load shifting, peak shaving, or balancing intermittent renewable energy sources. This baseline is crucial for effective grid management, enabling a more responsive and efficient energy system that can adapt to varying demands and supply conditions.

Market clearing is the process of matching demand and supply in the market. It refers to the process of determining the equilibrium price and quantity at which the total demand for a good or service matches the total supply. In simpler terms, it's the point at which the quantity of a product that producers are willing to supply equals the quantity that consumers are willing to buy. The market clearing price is the price at which this equilibrium is reached. This price is often determined through auction mechanisms or other market-based methods. The goal of market clearing is to efficiently allocate resources by ensuring that the quantity of goods or services supplied equals the quantity demanded, minimising surpluses or shortages in the market.

6.3 Technical Prequalification

6.3.1 Analysis of the principles and practices for the design of the technical prequalification procedure

The design principles for prequalification described in section 3.3.1 as outlined in [15], [34], were scrutinised and discussed with OneNet partners and demonstrators to assess their validity and applicability in real-world contexts.

The viability of the recommendation to avoid unnecessary redundancies in prequalification process depends on the product considered since different products can be characterised by different attributes that define peculiar requirements for the prequalification process. Hence, a single standardise prequalification process for standard balancing products seems applicable, however, considering specific balancing products and non-balancing products, the provided recommendation seems challenging to be satisfied and would require as a preliminary necessary condition the definition of the ToE. In this scenario, simplified ex-post verification

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processes seems challenging to be adopted since the adoption of simplified procedures since the lack of ToE, clear definition of non-simplified ex-post verification process, and experience with historical information.

Considering grid prequalification redundancy avoidance, it is worth noting that grid prequalification is a SO-specific activity, i.e., each system operator can prequalify its own grid only, hence, in case grid segments under different SOs are involved in the service provision, multiple grid prequalification processes are required. However, a coordinated grid prequalification of the different grid segment allows simplifying the process and increase its efficiency.

Among the recommendations for simplification, [15], [34] recommend for local SO services avoiding adopting the ex-ante activation test as a prerequisite. It is acknowledged that this recommendation aims reducing the market access barriers, however, ex-ante activation test is seen by OneNet SOs and other technical partners as the main channel to proof the reliability of SPs. This aspect is considered of paramount relevance since the security and quality of supply can be jeopardised in case of misbehaviour of the SPs to called by SOs for network operation support. Therefore, any measure substituting ex-ante activation test have to guarantee the necessary level of confidence in terms of SPs reliability. Among the several options discussed with OneNet partners, the adoption of certified technology for SPs equipment may represent a condition that may make ex-ante activation test unnecessary. However, in any case, an effective penalisation scheme for SPs that do not comply with the service provision requirements is necessary to incentivise the adoption of the solutions ensuring the adequate level of reliability.

Recommendation such as the definition of verification criteria for ex-post product verification and the definition of an appropriate proportionality for prequalification burden for service providing units and groups would require further elaboration since both appear to be highly case dependent. Hence, a detailed audit and analysis of the possible cases considering SO needs and context characteristics are required to further elaborate guidelines that can drive the application in real cases of procedures that pursue those recommendations.

According to the analysed documents and the consultation moments within the OneNet project, the prequalification procedure ideally would involve a balanced approach that prioritises post-market compliance checks, tailors the prequalification burden to actual risk and resource size, simplifies processes while maintaining technical integrity, eliminates unnecessary duplication, and intelligently manages changes in service provider capabilities. The key elements synthesising the ACER document, the proposal for a network code on demand response and the perspective of OneNet partners on an appropriate prequalification process are:

- Ideally the prequalification procedures should prioritise ex-post verification over ex-ante prequalification, except for standard balancing products. This approach is echoed in both the ACER document and the Network Code on Demand Response, emphasising the importance of post-implementation checks to ensure compliance and operational integrity without placing undue upfront administrative burdens on service providers.

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- Ex-post verification processes are encouraged to simplify and expedite the market entry process for service providers. This can be facilitated by certified equipment and flexibility registers that track compliance and performance. Penalties for non-compliance serve as a deterrent and ensure adherence to the operational requirements.
- The burden of prequalification should be proportionate to the risk and impact on the grid and the size of the resource, reducing the barriers for smaller and standardised devices ensuring that the requirements are not unnecessarily stringent and do not stifle the market participation of SPs. However, further analysis is required to define the correspondent implementation guidelines.
- The procedures should be as simple as possible, avoiding complexity unless specific technical requirements are not met. This recommendation is a general principle that can be applied to any procedure of the electricity sector, in which procedures have to aim to be user-friendly, technologically neutral, and transparent while ensuring that technical requirements for grid stability and service delivery are met.
- To avoid redundant procedures, when multiple System Operators (SOs) are procuring the same product, a common prequalification should be established. When multiple SOs are potential buyers of the same product, they should agree on one entity responsible for prequalification. Additionally, the ToE have to be designed to avoid duplication and optimise registration and prequalification processes by harmonising requirements for similar products across that may be acquired by different SOs.
- A contribution to simplification entails how to handle changes in aggregated units. When there are changes in the technical characteristics of aggregated units, re-prequalification should be considered only if these changes impact the technical capabilities of the entire group. Significant changes in prequalified units that are relevant for service provision should trigger a new prequalification process. However, as in the case of the prequalification burden definition, further studies are required to determine clear criteria that ensure that the modified units still meet the required standards for service delivery.

6.3.2 Analysis of the demo design for prequalification

Whenever possible the adoption of common prequalification phases is considered positive since it goes in line with the harmonisation of the technical requirements determining a cross-SO impact characterised by knowledge sharing and best practices across the SOs community. Moreover, it would be beneficial for market efficiency since it would determine a positive market access impact allowing cross-SO investments for SPs enabling economies of scale.

Hence, the OneNet demonstrators' solutions regarding the adoption of common grid and product prequalification procedures have been analysed to identify the potential for widespread adoption or barriers to harmonisation. The analysis has considered three dimensions: the harmonisation of prequalification procedures for multiple products, System Operators (SOs), or considering Service Provider (SP) units and groups.

Table 6.1 provides an overview of the solutions adopted by the OneNet demonstrators in terms of harmonised grid prequalification procedures; while

Table 6.2 concerns the solutions adopted by the OneNet demonstrators for harmonised product prequalification procedures. Table 6.1 and

Table 6.2 show only the OneNet demonstrators dealing with harmonised procedures across the three dimensions for the analysis.

The dimension for the analysis described in Table 6.1 and

Table 6.2 are:

- Common prequalification across products refers to the implementation of a harmonised prequalification process that is applicable to multiple different products. Instead of having separate prequalification procedures for each product, there is an effort to establish a shared or common set of criteria and processes that can be applied across a range of products.
- Common prequalification across SOs refers to the concept of a harmonised prequalification process that is applicable across multiple SOs. Instead of each SO having its distinct prequalification procedures, there is an effort to establish a shared set of criteria and processes that can be universally applied by different SOs.
- Common prequalification for SP aggregation refers to the process of grouping SPs as part of a prequalification procedure. In this context, the term "aggregation" implies bringing together multiple SPs, possibly based on certain criteria or characteristics, to collectively undergo the prequalification process. Prequalification procedures validity can apply to each single SP as a standalone entity or to a SP group.

As shown in Table 6.1, the harmonised grid prequalification procedures have been formalised for products related to balancing, congestion management, and voltage control services. Considering common grid prequalification procedures across SOs, Table 6.1 shows that the trend across OneNet demonstrators is the definition of dedicated procedure since this procedure imply technical verifications on grid portions that can be addressed only by the SOs in charge of operating that portion. However, OneNet demonstrators acknowledge the possibility of coordinating the grid prequalification of the different grid segments exploiting dedicated procedures (e.g., centralised optimisation operators, traffic light schemes, tunnels of warranties, and flexibility registers). The majority of analysed OneNet demonstrators established common grid prequalification for SPs units and groups, highlighting the potential for simplification of grid prequalification procedures for this dimension.

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Table 6.1: Overview of the solutions adopted by the OneNet demonstrators in terms of harmonised grid prequalification procedures

	Common grid prequalification across products	Common grid prequalification across SOs	Common grid prequalification for SP aggregation
NOC	Balancing and Congestion Management	TSO and DSO (centralised through the Optimisation Operator)	Service Providing unit and group
CZE	Congestion Management and Voltage Control	Dedicated for the DSO	Service Providing unit and group
POL	Balancing, Congestion Management, and Voltage Control	Dedicated for TSO and for DSO	Service Providing unit
GRC	Balancing, Congestion Management, and Voltage Control	TSO and DSO	Service Providing unit
PRT	Congestion Management and Voltage Control	Dedicated for TSO and for DSO	Service Providing unit and group
ESP	Dedicated for Congestion Management	Dedicated for the DSO	Service Providing unit and group

Table 6.2 illustrates that OneNet demonstrators have developed solutions to establish a common prequalification procedure for products related to Balancing, Congestion Management, and Voltage Control services. Additionally, common product prequalification procedures across System Operators (SOs) are defined, emphasising that this process is likely to be shared among different system operators, unlike grid prequalification procedures. This is because the stringent requirement related to the knowledge of the grid no longer persists. Therefore, in alignment with the prequalification process design principles outlined in Section 6.3.1, product prequalification can be addressed once, and its validity extends to all SOs involved in the acquisition process. All demonstrators analysed define a common product prequalification procedure for SP aggregation.

Table 6.2: Overview of the solutions adopted by the OneNet demonstrators in terms of harmonised grid product prequalification procedures

	Common product prequalification across products	Common product prequalification across SOs	Common product prequalification for SP aggregation
NOC	Balancing and Congestion Management	TSO, DSO (centralised through Flexibility Register Operator)	Service Providing unit and group
POL	Balancing, Congestion Management, and Voltage Control	TSO and DSOs	Service Providing unit and group
PRT	Congestion Management and Voltage Control	TSO and DSO	Service Providing unit and group

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ESP	Dedicated for Congestion Management	DSOs	Service Providing unit and group

6.3.3 Analysis of barriers for large scale adoption of OneNet solutions on harmonised prequalification procedures

The OneNet project aims developing and demonstrating solutions that can be employed for large scale implementation in real conditions to achieve the goal of one market design for all Europe. With this regard, the potential and barriers for large scale implementations of the OneNet demonstrators' solutions has been discussed to identify best practices and critical aspects that require further efforts.

Based on the demonstration experience, the majority of demonstrators dealing with harmonised grid prequalification affirm that the procedures proposed in OneNet can be used as they are for real implementation. In some cases, e.g. the Czech demonstrator, it is highlighted that some adjustment may be required depending on the evolving regulatory landscape that is currently under discussion at country level. The Northern demonstrators highlight the need for further analysis to define the conditions that require a new group SP prepublication in case of changes in some units before implementing their solution in real environments. A point in common between the Northern and the Polish demonstrator regards the opportunity to address the grid prequalification in trading phase, rather than in prequalification phase. Having a grid prequalification procedure during grid validation, but still before activation phase, would make the procedure more dynamic and efficient.

The demonstration experience of the Greek demonstrator highlights that the Common grid prequalification procedures across products are not suitable for large scale implementation due to the different characteristics/ attributes and nature of service. However, considering common prequalification procedures across SOs and different SP aggregation, the demonstrated procedures are suitable for large scale implementation properly accounting for the implementation complexities and the future evolution of the market participation conditions.

The Portuguese demonstrator's experience highlights that the TSO and DSO have their own internal processes for grid prequalification, the demo only addresses the coordination part. In fact, a SP connected at the DSO network, to be prequalified to provide a service at the TSO level, need to go through a product conducted by the TSO and a grid prequalification conducted by the DSO.

Considering product prequalification, the OneNet demonstrators affirm that the developed and demonstrated procedures are suitable for real-contexts implementation. Also for product prequalification, the Northern demonstrators' experience underlines that the conditions for new group prequalification requirements require further analysis. The Portuguese demonstrator experience led to a solution that is well suited to the Portuguese landscape characterised by a TSO and a large DSO; hence, the replicability of the Portuguese solutions to different contexts may require further adjustments.

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The analysis of the barriers for the large-scale adoption of OneNet solutions on harmonised prequalification procedures is complemented by demonstrators' perspective considering the main aspect to be considered in that stage.

6.3.4 Analysis of the demo design drivers for large scale harmonised prequalification procedures adoption

The analysis of the prequalification phase design experience of the relevant OneNet demonstrators led to the identification of the set of key potential benefits and treats that drive the decision-making process, and the recognition of a set of requirements, enablers and barriers associated with adoption in the real context of harmonised prequalification procedures. The identification and recognition of design elements for the prequalification phase was addressed in the OneNet project by surveying the relevant demonstrators, who were given a set of definitions and asked to rank them in order of perceived relevance and to justify their response. The main results of the questionnaire analysis are presented in this section, and the full set of proposed definitions and rankings are provided in the Appendix 9.3 "Survey on the demo design drivers for large scale harmonised prequalification procedures adoption.

Common prequalification procedure across SOs – Benefits and Threats

Considering harmonised prequalification procedures aimed at defining a common framework for SOs, the main benefits identified are:

- Enhanced Coordination: It would foster better coordination between transmission and distribution levels.
- Optimised Utilisation: With shared prequalification, a flexibility resource could be used more efficiently across both levels of the grid, ensuring optimal system operation.
- Reduced Administrative Burden: A shared procedure would reduce the administrative and operational burden on service providers who work with both DSOs and TSOs.

Common prequalification procedures are perceived as drivers for improving the coordination between DSOs and TSOs. OneNet initiatives such as the F-channel (Greek demonstrator) [57] and the flexibility register (Northern demonstrator) [45] contribute to this end. Several demonstrators are focused on the optimisation of the coordination between the DSO and TSO. Common procedures allow to increase the overall efficiency of the prequalification process.

Moreover, shared prequalification is considered enablers for a more efficient utilisation of flexibility resources across the grid, optimising system operation. In all the cases in which a given resource is available to more than one SO, each SP that successfully completes the prequalification process is registered to the unified flexibility registry that is the same for all SOs. In such case after the TSO – DSO coordination each SP can be optimally used to satisfy the requests for SOs services from any SOs. OneNet solutions, such as the one of the

Portuguese demonstrator, allow for prequalification for provision of services to a level where the SP is not directly connected, e.g., SP being connected at the DSO level, providing services to the TSO, allowing also to not duplicating offers, activations, order coordination.

The reduced administrative burden is seen as a benefit for both SOs and SPs. Common prequalification procedures reduce administrative burden for SPs by eliminating unnecessary duplications. If a given SP will cooperate with different SOs, the possibility of simplifying the procedure and not having to duplicate the operation is beneficial from the system perspective. Solutions like the F-channel allows to an SP to be prequalified regardless how many SOs participate. If the grid prequalification process is completed successfully the SP is added to the unified SP registry and is ready for service provision to any SOs. However, it is worth noting that not all the SPs participating in the DSO local market will be able to participate in TSOs market because of minimum MW requirements.

When contemplating harmonised prequalification procedures aimed at establishing a shared framework for System Operators (SOs), the main threats identified, though expected to have low relevance, are worth discussing:

- Potential for Conflicts: DSOs and TSOs have different operational objectives and responsibilities, which could lead to conflicts in determining shared standards and in operating the jointly qualified resources.
- Complexity: Reaching consensus on standards that cater to the unique needs of both DSOs and TSOs could be challenging. A unified standard might not provide the flexibility needed for unique regional or operational challenges faced by individual DSOs or TSOs.
- Implementation Challenges: Transitioning to a shared procedure could entail significant operational and administrative changes, possibly causing disruptions.

The potential for conflicts between TSOs and DSOs is considered not of primary relevance since DSOs and TSOs already know each other's roles and have to cooperate closely in many respects. Moreover, operating the jointly qualified resources is not a part of the prequalification process. However, the divergent requirements and objectives of TSOs and DSOs present a significant challenge during the actual deployment of the tested solution. This includes the prequalification of tangible assets for service provision, where considerations like prioritisation of services need to be addressed and agreed upon by the involved parties (DSOs, TSOs). Furthermore, the requirements are essentially identical, with only complementary aspects in some areas but never contradictory. Establishing a common position between TSOs and DSOs can be challenging, especially when dealing with a larger number of operators. It is crucial to have clear regulations and guidelines at both the national and European levels that distinctly define the scope of products and services. The risk of a standard procedure failing to address the unique challenges of an operational system is relatively small. Solutions like the F-channel procedure aim to be more generic, covering the requirements of both SOs and allowing each SO to request additional input from the SP. This challenge was also addressed in the Portuguese demonstration by

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developing a custom-based data model that accommodates the needs of both the TSO and DSO, aligning with the objectives of the use cases.

The complexity is not considered a critical element, as achieving a common prequalification is possible even without full harmonisation of standards for data exchange or common product definition. However, as prequalification is a one-time process, any complexity may be limited in duration rather than being linked to ongoing operational challenges.

Implementation challenges are also perceived as not posing a significant threat, particularly since flexibility markets in many OneNet demonstrators are being developed essentially from the ground up. This entails adapting the systems of individual DSOs and TSOs, potentially incurring one-time costs for implementing a unified interface. While any modifications introduce additional work and the transition period may be challenging, the substantial added value of a common procedure is noteworthy. The deployment of common procedures may present challenges in terms of adjusting existing processes and, potentially, regulations, also posing complications for small SPs participating in only one market.

Common prequalification procedure across SOs – Requirements, Enablers, and Barriers

Considering harmonised prequalification procedures aimed at defining a common framework for SOs, the main requirements identified are:

- Interoperable platforms for prequalification: To ensure seamless and timely information exchange across the System Operators' control centres, there is the need for interoperable platforms and data exchange protocols.
- Shared Data Repositories: Platforms where relevant data is collated, standardised, and made accessible to relevant entities, ensuring transparency and promoting trust.
- Uniform Prequalification Criteria: While the specific operational requirements of DSOs and TSOs may differ, the outcome of the prequalification procedure must adhere to a common set of criteria ensuring interoperability.

Prequalification is not time-critical, thus, high-performance communication channels with control centres are not imperative. The necessity for interoperable platforms is contingent on the architecture employed, whether centralised or decentralised. In a centralised architecture, SOs do not need to exchange data with each other but with a central component, the Flexibility Register. Regardless of the architecture adopted, interfaces suffice to address common prequalification, facilitating communication among TSOs, DSOs, and SPs. Data exchange between SOs and current or potential SPs typically functions seamlessly in daily operations. To enable an efficient prequalification process, harmonising the communication among platforms involved is crucial, necessitating agreement on common data models—a prerequisite observed in the Portuguese demonstration.

Ensuring interoperability between platforms and internal systems and tools is also vital for SPs participating in both TSO and DSO markets.

A shared data repository for prequalification primarily consists of elements like the Flexibility Register like the one developed by the OneNet demonstrator [45]. The Portuguese demonstration adopts a decentralised approach, employing separate databases for the DSO and TSO that are synchronised with each other [58]. The OneNet F-channel incorporates a database containing characteristics, attributes, and calculations related to all actors, providing access to the open portion of this data for all involved parties [57]. While crucial, the privacy and confidentiality of data must be carefully considered, as certain information cannot be shared due to privacy and security reasons. Although beneficial, shared data repository are viewed as not a strict requirement, establishing robust communication between platforms that allow sharing data is deemed more crucial.

The establishment of uniform Prequalification Criteria is deemed particularly significant, especially when common TSO and DSO products are utilised. This enhances transparency and replicability of the process, recognising that specific requirements may vary while proving effective for similar markets or products.

Considering harmonised prequalification procedures aimed at defining a common framework for SOs, the main enablers identified are:

- Regulatory Support: Clear mandates and guidelines from regulatory authorities can act as a significant enabler. A framework that allows for adaptability as technology and market dynamics evolve, but still ensures system security and reliability.
- Pilot Projects and Test Beds: Initial pilot projects can help understand the challenges and benefits before full-scale implementation.
- Digital Twins: Creating virtual replicas of the physical grid system to run simulations, test and optimise shared prequalification procedures without affecting the real system.

Regulatory Support stands out as one of the most pivotal facilitators to consider, as an inadequately defined regulatory framework can become a hindrance to deployment. A framework that explicitly outlines procedures and actively encourages the development of smart and innovative solutions is essential. Clear rules benefit all stakeholders involved in the process. Regulatory Support holds particular significance in countries where flexibility markets are emerging or being developed, as seen in the case of Poland and Greece. Precise guidance and support from the regulatory authorities are invaluable in this regard, provided that those at the regulatory helm possess sound knowledge, the establishment of such a framework could serve as a significant facilitator.

Pilot projects and test-beds play a crucial role, particularly in initiating cooperation between TSOs and DSOs, as OneNet has shown. Pilot projects are invaluable as they provide an opportunity to gain knowledge, assess challenges and gain insights before committing to large investments. All OneNet pilots provide valuable results for the implementation and operation of a full-scale flexibility platform. In addition, linking them to regulatory

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experiments is essential to test solutions without regulatory constraints. This approach not only facilitates the improvement of solutions, but also helps to reshape regulations to better accommodate these innovative solutions.

Digital twins are undeniably interesting, but simulations may not always accurately reflect real-world behaviour. The 'what if' scenarios played out in simulations can sometimes be deceptive. Nevertheless, it is prudent to test concepts in simulated conditions before widespread implementation, even though the creation of a comprehensive digital twin in this area poses significant challenges. Grid power flow simulations are considered effective in accurately replicating the impact of, for example, flexibility applications. This is critical not only to assess the potential for SPs to address identified congestion, but also to prevent congestion as a result of activations. While TSOs are already using systems to run simulations, the lack of common information models is a challenge. For DSOs, a more detailed model of the transmission system would be valuable for conducting in-depth studies.

When contemplating harmonised prequalification procedures aimed at establishing a shared framework for System Operators (SOs), the main barriers identified, though expected to have low relevance, are worth discussing:

- Operational Inertia (or Path Dependency): Established operational protocols might resist change.
- Differing Objectives: DSOs and TSOs have different operational goals which can act as a barrier.
- Data Privacy Concerns: Sharing information between entities might raise data privacy and security concerns.

Operational Inertia (or Path Dependency) is not considered a significant barrier, as most procedures related to prequalification are entirely new, given the absence of existing flexibility markets in OneNet countries. The solutions tested within the OneNet demonstrators introduce novel concepts rather than replacing any existing platform or tool. Therefore, this barrier is not deemed relevant. However, operational protocols are essential to facilitate large-scale deployments of solutions.

Different DSOs and TSOs objectives do not represent a barrier because common prequalification against common products and shared grid information are the key elements of the solution by design, i.e. it is a design prerequisite. DSOs and TSOs have only partially different objectives, but one without the other will not fulfil theirs.

Data Privacy Concerns are crucial to address, but they do not act as a significant barrier because consent management is a fundamental aspect of the solution's design. It is essential to establish rules that prioritise data security, prevent misuse, and ensure that all data exchanges comply with relevant laws and regulations. Handling sensitive data from both SOs is a major challenge, as evidenced during the deployment of the OneNet

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Connector, where cybersecurity restrictions in the SOs' systems hindered deployment. The sharing of information will require the signing of non-disclosure agreements between the involved parties.

Common prequalification procedure across products – Benefits and Threats

Considering harmonised prequalification procedures aimed at defining a common framework for multiple products, the main benefits identified are:

- Reduced Administrative Burden: Sharing a single prequalification procedure for multiple products can simplify the administrative process, reducing costs and effort for both system operators and potential providers.
- Value Stacking for Providers: Providers might find it easier to pivot between different system services, based on market needs and price signals, if they have already been prequalified for a range of products.

The reduction in administrative burden stands out as one of the primary benefits of implementing a common prequalification procedure across products. In the OneNet project, this is achieved by minimising the variety of products themselves—allowing the same product to serve various needs. Each SP undergoes prequalification once for all products, and on the platform, SOs can ascertain which products are verified for each SP. This aligns with one of the main objectives of the OneNet demonstrations: defining harmonised and optimised processes for information exchange between DSOs and TSOs to enhance overall efficiency. While the unification of procedures and standardisation contributes to increased efficiency, it may not fully cater to unique product needs, as each product can have distinct requirements.

Value stacking for providers drives the design of OneNet's harmonised prequalification, as OneNet demonstrators seek to leverage customer flexibility in the most cost-effective manner across different markets. This is a pivotal aspect and a foundational principle of the demonstration, as the coordination process tested aims to enable the prequalification of SPs to provide services to networks where they are not directly connected. If an SP possesses the technical capability to meet requirements for various products, undergoing the prequalification process once instead of multiple times is advantageous for the SP. After completing the prequalification process for a range of products, an SP can offer different services. However, this is only relevant for SPs capable of participating with more than one product.

When contemplating harmonised prequalification procedures aimed at establishing a shared framework for multiple products, the main threats identified, though expected to have low relevance, are worth discussing:

- Potential for Lowered Standards: One size does not always fit all. A shared procedure might not adequately address the unique requirements of each product, leading to reliability issues.
- Complexity: Merging various criteria for different products into a unified prequalification process can result in a more complex and confusing procedure rather than simplifying it.

The potential for lowered standards is not perceived as a threat, as solution such as Flexibility Register would automatically conduct the product prequalification of resource groups against all available products. If a customer opportunity with sufficient financial potential is identified, individual adjustments on the customer's side can always be made to meet the standards. In general, the simplification of the procedure should not compromise any requirements, especially technical ones. Harmonised prequalification procedures should be designed based on the harmonised products, like the ones proposed by OneNet. Some products, such as local products, may have unique requirements compared to other products typically transacted in the TSO ancillary services market. Therefore, in these cases, prequalification procedures may have different requirements.

Complexity is not deemed a threat, as although the overall process may become more intricate, the complexity will only experience a slight increase since most parameters for different products remain identical if harmonised products are adopted. This situation is likely to arise whenever a unified solution must meet diverse expectations. While more tailored requirements and procedures invariably introduce higher complexity, the general process should still be harmonised to enable interoperability, even if not universal. However, complexity may pose a particular challenge for small SPs participating only with one product.

Common prequalification procedure across products – Requirements, Enablers, and Barriers

Considering harmonised prequalification procedures aimed at defining a common framework for multiple products, the main requirements identified are:

- Pilot Testing: Before fully implementing a common prequalification procedure, pilot testing could be conducted to assess its viability and adjust it based on real-world feedback.
- Standardised (Unified) Technical Requirements: Universal technical specifications (i.e., standardised or harmonised product specifications) for products across different system services can make shared prequalification more feasible. Consensus on the technical requirements that ensure the stability, safety, and efficient grid operation.
- Unified Regulatory Framework: Unified regulatory framework and guidelines for all system services can smoothen the transition towards shared prequalification (i.e. Table of Equivalence).
- Interoperable IT Systems: Systems that are compatible across different services can seamlessly share and process data, making shared prequalification more efficient.
- Neutrality: The prequalification process should be designed with a clear understanding of the market dynamics, ensuring that it does not unintentionally stifle competition or favour a particular set of providers.

Pilot testing, as with harmonised prequalification across SOs, is deemed essential to initiate such efforts, with OneNet serving as a notable example. It is considered a standard procedure. Pilot testing is always beneficial, particularly before transitioning solutions to daily operational activities. It is crucial to analyse

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challenges and risks before full implementation. However, the piloting period should not become a bottleneck, meaning it should be adequately defined to ensure the timely adoption of solutions, considering the opportune timing.

Standardised (Unified) Technical Requirements, or harmonised ones, are crucial for establishing clear rules in the prequalification area. These requirements inherit the structure defined for harmonised products and their attributes, using the same approach and format. Running product prequalification for each product becomes straightforward when considering harmonised products (e.g., harmonised attributes in OneNet). However, it is essential to consider the specificities of the service itself when defining such requirements.

The Unified Regulatory Framework is a valuable tool that should be developed at the EU level to offer support for national regulations and operators. Many OneNet countries currently lack an existing regulatory framework for flexibility markets. It is crucial to define all processes and roles clearly within the regulatory framework, as having clear rules will assist all stakeholders participating in the process.

Interoperable IT systems, or a single system such as the Flexibility Register, are essential to enable harmonised prequalification procedures for all products. Currently, SOs management systems are diverse and there may be no need for them to be unified in the future. It is essential to establish a common interface to facilitate essential communication and data exchange between the relevant market actors. The OneNet platforms have prioritised this aspect as a core requirement for ensuring interoperability with SOs' internal tools and systems. In addition, these systems need to interact with each other, which requires interoperability, where the messages exchanged between them are seamlessly understood.

Neutrality is a requirement, aligning with the European Directive 2019/944. However, in the creation of unified solutions and combined procedures, some freedom is inevitably lost, potentially leading to exclusion. SOs play a role as facilitators of the transition and neutral parties. Ensuring fair competition is paramount, with a focus on system security and the quality of service.

Considering harmonised prequalification procedures aimed at defining a common framework for multiple products, the main enablers identified are:

- Transparent and Uniform Procedures: Procedures that are transparent and uniform across services can simplify the prequalification process and make it more accessible. A common procedure should ideally simplify the documentation process, making it easier for providers to understand and comply with the requirements.
- Clear Economic Benefits: Clear economic benefits, such as cost savings, increased efficiency, or better resource allocation, make shared prequalification more attractive. If all the stakeholders, including service providers, regulators, and consumers, see the benefits are onboard with shared prequalification, it can be smoothly implemented.

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Transparent and uniform procedures are essential, allowing SPs to leverage experts who can navigate the regulatory environment, potentially providing a competitive advantage. A standardised approach is preferable, particularly for new procedures where processes and roles are still unclear, enhancing document circulation and the overall procedure. Clear procedures contribute to increased customer engagement.

Clear economic benefits should serve as the primary motivator for change. Clearly outlined advantages for various entities participating in the flexibility market contribute to increased market liquidity and openness. Minimising overall system costs is an important driver in adopting new solutions, whether it be a shared prequalification process or otherwise. However, this consideration should be balanced with the technical benefits it brings to the system. Demonstrating clear economic benefits will enhance customer engagement.

When contemplating harmonised prequalification procedures aimed at establishing a shared framework for multiple products, the main barriers identified, though expected to have low relevance, are worth discussing:

- Complex Integration Procedures: If integrating the prequalification processes of different services becomes too complex, it might be more efficient to keep them separate.
- Lack of Stakeholder Consensus: Resistance from any key stakeholder can halt the progress towards shared prequalification.
- Conflicting Regulatory Mandates: If regulation for different system services have conflicting requirements or standards, shared prequalification becomes challenging.

Complex integration procedures are not considered a significant barrier; however, it is acknowledged that using the same prequalification process for different services adds complexity with each SP successfully prequalified for multiple services. Given that the primary goal of the OneNet demonstrations is to optimise processes and reduce complexity, this becomes an aspect to address with the aim to maintain simplicity to enhance customer engagement.

Lack of Stakeholder Consensus is extremely important in the case of a very fragmented market and a large number of actors (number of DSOs and TSOs involved). However, no lack of consensus between the key stakeholders has been experienced in the OneNet project.

Conflicting regulatory mandates would be a significant concern, but it is not anticipated to occur. Legal regulations should guarantee the introduction of a common procedure and permit it. The regulatory framework should be designed to prevent conflicting requirements of

Common prequalification procedure for single units and groups – Benefits and Threats

Considering harmonised prequalification procedures aimed at defining a common framework for standalone units or as aggregated entity, the main benefits identified are:

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- Market Accessibility for Small Units: Establishing prequalification at the portfolio level allows for the aggregation of small units or assets that individually might not meet the minimum size or capacity requirements for standalone prequalification.
- Risk Diversification: Risks associated with individual assets can be offset by the performance of others, creating a more resilient and stable portfolio.
- Versatility: A portfolio can provide a more versatile response to service requests or market conditions, leveraging the combined capabilities of different assets.
- Economies of Scale: Aggregating multiple assets can lead to cost savings in prequalification, operation, and management.

Aggregating small assets into a larger unit can provide benefits, facilitating market access for small units. This is crucial for participation in TSO markets, allowing asset owners/aggregators to submit higher bid offers and participate in markets with higher minimum size or capacity requirements. It enhances customer engagement.

Risk diversification is the primary benefit of portfolio prequalification. From the TSO's perspective, this is valuable as it provides versatility to meet system needs. However, from the DSO's viewpoint, it is meaningful only if the resources are from the same required location. Creating a portfolio for location-related services poses challenges, particularly in defining location granulation and considering assignments to specific network elements. Creating a portfolio is completely different if it is required to assign resources from the LV network to MV/LV stations and to a specific feeder or LV connection point. The DSO holds the necessary knowledge for such assignments.

Versatility is seen mainly a benefit for aggregators that manage multiple sources of flexibility with different characteristics.

Economies of scale make sense from the SP side and could be relevant; however, it may differ depending on the type of assets, as observed in some OneNet demonstrators (e.g., Polish demo). The time consumption and the need to prequalify individual resources, often multiple times, can be very burdensome, especially in the case of a large number of resources. However, economies of scale potential will depend on the cost of aggregations.

When contemplating harmonised prequalification procedures aimed at defining a common framework for standalone units or as aggregated entity, the main threats identified, though expected to have low relevance, are worth discussing:

- Standardisation Challenges: Different assets might have different standards or come from different vendors, leading to integration and standardisation issues.
- Operational Challenges: Maintaining consistent performance across a diverse portfolio can be challenging, especially if individual assets have distinct operational requirements.

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Standardisation challenges can indeed complicate integration and require extra testing to ensure that all IT and communication issues are compliant. However, these challenges may be addressed by intermediaries such as aggregators or other service providers.

Operational challenges should be addressed based on their characteristics. Managing a very diverse portfolio can be difficult, but this can be mitigated by creating groups of resources with similar natures of work and technical parameters. Additionally, an advanced monitoring and control system may be required to avoid undesired challenges for SPs/aggregators and SOs.

Common prequalification procedure for single units and groups – Requirements, Enablers, and Barriers

Considering harmonised prequalification procedures aimed at defining a common framework for standalone units or as aggregated entity, the main requirements identified are:

- Advanced Monitoring & Control Systems: Systems capable of gathering real-time data and controlling multiple assets in the portfolio.
- Portfolio Management Framework: A comprehensive framework that can capture the synergies and complexities of diverse assets in a portfolio.
- Detailed Asset Documentation: Information on each asset's capabilities, constraints, history, and operational characteristics.

Advanced monitoring and control systems are crucial for the activation of assets but are not needed in prequalification. Monitoring systems, which include forecasting, visualisation, and real-time monitoring, are essential for evaluating portfolio performance. This holds true for all solutions, not just portfolios.

The portfolio management framework is handled by the optimisation module of the OneNet TSO-DSO Coordination Platforms and Flexibility Register. However, its relevance lies in the trading phase rather than prequalification, A comprehensive framework for a diverse portfolio is crucial for the trading phase.

Detailed asset documentation, including information like location, is deemed critical and is stored in the Flexibility Register. Proper documentation of the capabilities of portfolio assets is also essential, both with and without portfolios.

Considering harmonised prequalification procedures aimed at defining a common framework for standalone units or as aggregated entity, the main enablers identified are:

- Advanced IT Systems: Modern IT platforms that can process large datasets, employ analytics, and provide insights on the entire portfolio.
- Regulatory Support: Regulations that encourage or allow for portfolio-level prequalification.

Advanced IT systems are crucial for both individual aggregators managing their portfolios and for centralised system management, exemplified by the Flexibility Register. They play a vital role in evaluating and tracking portfolio performance, serving as indispensable enablers for the prequalification procedure of resource portfolios. These systems not only enhance efficiency and accuracy in resource evaluation but also provide valuable insights through data analytics and reporting. Consequently, they contribute to more informed decision-making and improved resource management across various industries and domains.

Regulatory support is considered relevant as market participants require legal and regulatory confidence. A robust regulatory framework is crucial as the foundation to incentivise and adopt the prequalification procedure for resource portfolios. It involves defining clear rules, roles, and responsibilities. National Regulatory Authorities (NRAs) must establish rules for aggregation.

When contemplating harmonised prequalification procedures aimed at establishing a common framework for standalone units or as aggregated entity, the main barriers identified, though expected to have low relevance, are worth discussing:

- Data Privacy and Security Concerns: As more assets are interconnected, concerns about data breaches or unauthorised access might arise.
- Economic Hurdles: It might be financially challenging to integrate various assets or establish new systems for portfolio-level management.
- Resistance to Change: Established organisations might be resistant to moving away from individual asset prequalification due to the costs or perceived risks.

The DSOs and TSOs manage critical infrastructures, thus, any data breaches or unauthorised access must be avoided and addressed. The platforms used shall be secure by design and aligned with cybersecurity standards and existing best practices.

Economic challenges pose a hurdle for aggregators, as integrating various assets into a single unit can be financially demanding. While this aspect may not have a significant impact during the demonstration phase, it could become a barrier, particularly at lower voltage levels where the volume and variety of assets involved are greater. The feasibility will depend on the cost of aggregation.

Resistance to change does not appear to be an issue in OneNet demo regions. Nevertheless, there should be flexibility in the approach, allowing those who prefer to handle each resource separately to have that option. Companies specialising in resource aggregation may opt for portfolio-level operations if feasible. However, the level of resistance to change may vary based on associated costs.

6.3.5 Risk assessment

The demonstrators were asked about the perceived hazard level and probability of the following identified risks for prequalification-related topics:

1. A unified prequalification adds significant implementation complexity and requires high costs

2. A unified prequalification adds potential for conflicts between TSOs and DSOs lowering reliability
3. Sharing information between entities might raise data privacy and security concerns leading to cybersecurity and legacy systems and data management requirements risks
4. Potential for Lowered Product Standards: A shared procedure might not adequately address the unique requirements of each product, leading to reliability issues.
5. Risk of Stifling Innovation: a unified procedure might inadvertently hinder these specialised innovations.
6. Risk for economic inefficiency and lack of reliability: technical requirements for different system services and different products are too varied, shared prequalification might introduce inefficiencies
7. Potential for Service Disruption: If there's a risk that shared prequalification might disrupt the provision or quality of system services, it can be a major deterrent.

Table 6.3 provides a summary of hazard levels and their perceived probabilities across various demos. A quick look reveals notable differences in the perception of hazard levels and risk probabilities associated with harmonised prequalification procedures. Demonstrations within WPs 7 and 10 generally perceive lower hazard levels and risk probabilities compared to those in WPs 9 and 10. There is no unanimous agreement among OneNet demonstrators regarding any risk except for risk No. 5 related to the stifling of innovation. This risk is considered of low relevance, as while standardisation may limit future flexibility in specific cases, dedicated channels for addressing the needs of such cases have to be made available to drive innovation when and where needed.

As discussed in section 6.3.4, complexity is not considered to be a critical element as it is possible to achieve common prequalification without full harmonisation of data exchange standards or common product definition. Although the overall process may become more complex, complexity will increase only slightly as most parameters for different products will remain identical to harmonised products. However, it is recognised that using the same prequalification process for different services will increase complexity as each SP will be successfully prequalified for multiple services. This may result in increased costs associated with service provision for SPs, and mitigating actions will need to be developed to mitigate the risk of cost increase.

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Table 6.3: The risks associated with large scale deployment of harmonised prequalification solutions with the perceived hazard level and risk probability. The risk levels are colour coded as follows: red – high risk, yellow – mid-level risk, blue – low risk, green – low risk.

Risk	Hazard level	Risk Probability	Hazard level	Risk Probability	Hazard level	Risk Probability	Hazard level	Risk Probability	Hazard level	Risk Probability	Hazard level	Risk Probability
	NOC		**CZE**		**POL**		**GRC**		**PRT**		**ESP**	
1	L	L	L	L	L	L	H	M	M	M	H	M
2	M	L	M	L	M	L	H	H	H	M		
3	H	L	H	L	M	H	H	H	H	H	L	L
4	M	L	L	L	H	M	H	M	H	H	H	H
5	L	L	L	L	M	L	L	L	L	L		
6	M	L	M	L	L	M	H	M	M	H	H	H
7	L	L	H	N	L	L	M	M	M	L	M	M

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The potential for reduced reliability is not seen as a relevant risk, as in general the simplification of the procedure should not compromise any requirements, especially technical ones. As mentioned in section 6.3.4, in general, harmonised prequalification procedures should be designed on the basis of harmonised products, such as those proposed by OneNet, which guarantee a comfortable level of reliability for SOs. However, in all cases where the need for harmonisation conflicts with the need for specific technical performance, a dedicated product and prequalification definition should be preferred to harmonisation.

Data privacy and cybersecurity concerns are considered the most important risk in terms of hazard level and with some relevance in terms of risk probability. The level of risk is mitigated by solutions that reduce the likelihood of risk, such as non-disclosure agreements between the parties involved, rules that prioritise data security, prevent misuse and ensure that all data exchanges comply with relevant laws and regulations. As pointed out in section 6.3.4, the involved platforms must be secure by design and aligned with the highest cybersecurity standards and existing best practices.

The potential for lower standards is not considered a relevant risk as the simplification of the procedure should not compromise any requirements, especially technical ones, as mentioned in section 6.3.4. This risk is considered to be low, as harmonised prequalification procedures should be designed on the basis of harmonised products, as proposed by OneNet. However, the risk may materialise in specific cases where some products, such as local products, may have unique requirements compared to other products typically traded in the TSO ancillary services market. Therefore, in these cases, prequalification procedures may have different requirements.

The risk of economic inefficiency and lack of reliability is considered somewhat relevant in terms of hazard level, but with a low to high probability of occurrence. A common prequalification process helps to minimise the total system cost and is an important driver for the adoption of new solutions. However, as discussed in section 6.3.4, economic challenges can be a barrier for SPs and aggregators who are interested in providing a specific product and are forced to go through a costly harmonised prequalification process, the outcome of which will not be fully exploited. Mitigating measures are needed to ensure that the costs associated with the harmonised prequalification process are not such as to discourage customer engagement.

Service disruption would be a significant hazard, but of low to medium probability. The needs of all SOs, including those responsible for system services, should be addressed and their expectations met. DSOs and TSOs have a mandate to ensure security of supply and quality of service, so any solution that may pose a risk must be properly assessed and may be abandoned if the risk is found to be too high. Therefore, in harmonised procedures, SOs also agree to exclude technical requirements in the prequalification process of potential providers that may later cause problems in the provision of services.

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6.3.6 Recommendations and Best Practices for Harmonising Prequalification

Adopting a common prequalification across products allows to streamline and simplify prequalification efforts, promoting value stacking for SPs and liquidity for the markets. While, a common prequalification across SOs allows to create efficient prequalification process, allowing for interoperability and collaboration among various System Operators.

Based on the experiences described in the OneNet project's demonstrators, the following recommendations for designing harmonised prequalification procedures could be considered:

- Flexibility in regulatory adaptation: recognise that while harmonised procedures can serve as a robust starting point, they may require adjustments to align with national regulatory landscapes, as seen in the Czech demonstrator experience. A harmonised European framework should provide guidelines that are adaptable to country-specific regulations.
- Prequalification timing: consider the Northern and Polish demonstrators' suggestion to address grid prequalification during the trading phase, rather than the prequalification phase. This approach could make the process more dynamic, allowing for adjustments based on real-time grid conditions and validation processes, leading to a more efficient system.
- Products diversification: acknowledge the Greek demonstrator's insight that common grid prequalification procedures may not be suitable for all products due to their diverse characteristics. This implies that while harmonisation is beneficial, product-specific nuances must be accounted for to ensure the procedures are applicable on a large scale. The adoption of the ToE for products is a necessary condition to enable common prequalification procedures across different products.
- Coordination across SOs for prequalification: emphasise the need for coordinated procedures across different System Operators (SOs) and Service Provider (SP) aggregations, as demonstrated by the Portuguese experience. This can help establish a more streamlined process for SPs that are connected to both DSO and TSO networks.
- Group prequalification analysis: Northern demonstrators' experience that suggests further analysis is required to define conditions for new group SP prequalification when changes occur in some units. This will help to determine when updates or re-evaluations are necessary without overburdening the system with frequent reassessments.
- Contextual replicability and scalability: Learn from the Portuguese demonstrator that while solutions may be well-suited to specific national contexts, replicability in different environments might require additional adjustments. Prequalification procedures should be designed with scalability in mind, allowing for adaptations to fit various market structures and sizes.

Moreover, due to the lack of empirical experience for all the involved actors, it is recommended establishing a continuous feedback and improvement loop that establish a system for ongoing feedback from demonstrators to continuously refine prequalification processes. This can include regular reviews, updates based on technological advancements, and modifications to address emerging market conditions. Furthermore, clear communication and transparency would ensure that all stakeholders have access to clear information about prequalification requirements and procedures. This transparency can increase participation by providing potential SPs with a better understanding of how to comply with the requirements.

6.4 Baselining

The need for a baseline for SPs emerges for small units that do not have an individual schedule from previous markets (e.g. wholesale energy markets) and provide SO services a counterfactual for the verification of service provision. This counterfactual is often called the baseline [59].

Based on the experience in the OneNet project, considering the future implementation of baselining in the markets and taking as a starting point the decisions reported in T3.4 [33], we ask the OneNet demonstrators to reflect on the answers provided and reply whether the demonstrator would change the choices made or the motivations related to the baseline methods.

Table 6.4 presents the reviewed baseline methods and considers the accuracy, simplicity and integrity principles, which are the main principles to evaluate baseline methodologies. A detailed description of these methodologies can be found in [59], but the main characteristics are:

1. **Data-Based Methods**: Many current methods rely on historical metered data. This includes the High X of Y method and its variations, where the baseline is calculated based on the average consumption of the highest usage days within a previous period (e.g. considering differently weekends and weekdays). Another approach is using a rolling average of previous days of the same type, with possible weighting for recent days to account for current factors like weather.
2. **Comparable Day Method**: This approach involves selecting a past non-activation day that mirrors the conditions of the event day, providing a baseline that reflects similar circumstances.
3. **Statistical and Regression Methods**: These methods use historical data to create models (linear or polynomial regression) that predict baseline consumption based on variables like past consumption, season, weather, and day of the week.

   Machine Learning Techniques: Recent advancements include neural networks and other machine learning algorithms for more accurate baseline predictions [60]. These techniques, such as Artificial Neural Networks (ANN), Convolutional Neural Networks (CNN), and Long Short-Term Memory (LSTM) algorithms, offer complex models that may be less transparent than traditional regression methods
4. **Meter-Before-Meter-After (MBMA)** method is used for short-term delivery products and does not require ex-ante estimation, just a measurement before and after the service delivery.
5. **The zero-baseline method**, used particularly for behind-the-meter backup generation, assumes a baseline of zero, treating any power injection during activation as flexibility provision.

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6. **Control group** method uses the average profile of a set of non-activated end-users with similar characteristics to the flexibility providers as the baseline.
7. **Self-declared** baseline is not characterised by specific properties but depend on the method employed by SPs for the calculation and reporting of its baseline.

Table 6.4: Qualitative assessment of baseline methodologies against baselining principles. Source: [33]

Baseline methods	Accuracy	Simplicity	Integrity
High X of Y	Medium	High	Medium
Regression	High	Low	High
Comparable day	Medium	High	Medium
Rolling average	Medium	Medium	Medium
Statistical sampling	Medium	Medium	Medium
Meter before/meter after	Medium	High	Low
Maximum Base Load	Low	High	Medium
Metering generator output	Medium	Medium	Medium
Machine learning	High	Low	High
Control groups	Medium	High	High
Self-declared baseline	Medium	High	Low

OneNet Deliverable 3.4 [33] identifies six relevant questions related to the regulatory options for baseline. From those questions, Table 6.5 presents the four of them to follow up on the decisions made by the demonstrators.

Table 6.5: Identified questions related to regulatory options for baselining

Question	Options that are discussed
Who is responsible for setting the baseline?	• System operator • (Independent) market operator • SP • Independent third party, e.g., regulator
Which type of customer is baselining applied to?	• Non-professional customers, e.g., residential customers or energy communities • Professional customers, e.g., (large) commercial or industry customers *
Which type of DER is baselining applied to?	• Isolated DER, e.g., heat pumps, PV/wind, back-up generation, combined heat and power, storage/batteries • Combined DER • Aggregated DER
Which product is baselining applied to?	• Frequency versus non-frequency product • Active versus reactive product • Short-term, long-term, and emergency (operational)

* in particular, where they do not have schedules set in other market segments

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6.4.1 Definition of the principles and practices for the design of the market phase

Six OneNet demonstrators implemented baselining in their activities: Northern cluster, Poland, Slovenia, Cyprus, Greece, and Spain. The baseline methods per products considered are presented in Table 6.6. The majority of the demonstrators opted for High X of Y method or self-declared baseline by the SP. Spain opted for a comparable day as information from individual schedules were available. The Polish and Slovenia demo opted for meter before- meter after method mainly for simplicity reasons.

Table 6.6: Overview of baseline methodology per product used in the OneNet demonstrators. Source: [33]

Product	Baseline methodology			
	High X of Y	Comparable day	Meter before/ Meter after	Self-declared by SP
aFRR	Greece			
mFRR	Northern, Greece		Poland	Northern
RR			Poland	
Corrective local active power	Northern	Spain	Slovenia	Northern, Cyprus, Spain
Corrective local reactive power	Greece			Cyprus
Predictive short-term local active power	Northern, Greece	Spain	Poland	Northern, Spain, Poland
Predictive long-term local active power	Northern	Spain		Northern, Spain

6.4.2 Analysis of the demo design for market phases, considering design motivation

Based on the gained during the demonstrators, the demonstrators were asked if alternative baseline methodologies could outperform from the ones tested (see Table 6.7). For the products demonstrated and alternative ones, only the Polish demonstrator considers that alternative baseline methods should be considered as a practical choice. For additional products the Slovenian demonstrator considers that if diverse resources participate additional methodologies need to be considered. For real implementation, the Northern cluster considers that it is too early to take a decision based on the demonstrators' activities, while the Spanish and Polish demonstrators agree that alternative methodologies need to be considered.

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Table 6.7: Alternative methodologies considerations after the demonstrators' experiences

Demonstrator	Alternative methodologies		
	For the demonstrated product	For additional products from the one tested	For real implementation
Northern	No	No	Too early to conclude
Greek	No, same as balancing market	No	No, a common methodology is desired
Spanish	No	No, but open to explore alternatives	Yes, alternatives have to be considered
Cypriot	No, the methodology is simple, accurate and effective	No, the methodology is general	No, methodology seems promising
Polish	Yes, it was very basic. Especially for power products	Yes, it needs to be revised and improved	Yes, the methodology needs to be revisited and improved
Slovenian	No	Yes, probably due to different customers as only heat pumps were tested	No

Regarding the responsibility of setting the baseline method, there is a mix of choices between the SO and the SP to become the default option to perform the baseline or an alternative option was also foreseen for some demonstrators (Table 6.8). In the case of the Northern cluster, depending on the product and the country, either the SP or the flexibility register can perform that task, when the SP has not provided the schedule in time or has decided not to do it, the flexibility register calculates the baseline ex-post. When the demonstrators were asked about the allocation of roles for real implementation, the Norther cluster considers that it is too early to decide, while the Spanish demonstrator considers that the decision made could change. Greek and Slovenian demonstrators consider that the SO should perform that task while Cyprus and Polish consider that is the SP that in real implementation should be in charge of providing baselines. The OneNet demonstrators' solutions to the responsibility for setting the baseline method are in line with the provisions of the draft proposal for the NCDR [34].

Table 6.8: Responsibility of setting the baseline methodology

Demonstrator	Responsible for setting the baseline in the demonstrator					Real implementation change
	System operator	Market operator	SP	Third party, e.g., regulator	Flexibility register	
Northern			Default option		Default option	Too early to conclude

Greek	Default option					No, TSO is responsible
Spanish	Alternative option		Default option			Responsible could change
Cypriot			Default option			No. SPs are reliable
Polish	Alternative option		Default option			No, SP should be responsible. Challenging for small users
Slovenian	Default option					No

6.4.3 Analysis of barriers for baselining harmonisation and submetering usage

The type of resources which could be aggregated and the use of submetering are key elements to decide among baselines methodologies. In the OneNet demonstrator different options were considered (Table 6.9).

Table 6.9: Baseline methods based on resource types and submetering usage

Demonstrator	Type of … involved in the demo		Aggregator involved?	Baseline calculated at de demo		Use of submetering?
	SP	Resource		individual asset level	aggregated portfolio level	
Northern	Residential, Commercial	Demand (heat pumps, water boilers, EV), PV	Yes (Estonia, Finland)	Yes		Yes
Polish	Industrial, Generators	PV, DSR, CCGT	Yes		Yes, at the level of scheduling units for balancing services	No
Cypriot	Household	Load reduction, RES generation, batteries	No	Yes (at metering point)		Yes
Spanish	University, Industrial	Load reduction (air conditioning, heat pumps)	Yes		Yes	Yes

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Slovenian	Household	Heat pump, battery, PV	Yes	Yes	Yes	No
Greek	Generators, Residential, Industrial	RES, conventional units, load reduction	No	Yes		No

The participation of small customers without the individual schedule is the main reason for opting for baseline methods. These customers may need to be aggregated to participate in the provision of SO services. But the involvement of an aggregator does not necessarily mean that the baseline is also calculated at the aggregated portfolio level. For real implantation, the demonstrators agree that the individual baseline is a more accurate solution. Only the Spanish and Slovenian demonstrators consider also the portfolio baselining as a possibility (Table 6.10). In addition, the majority of the demonstrators consider that submetering can be used for settlement purposes, the exception are the Polish and Slovenian demonstrators that argue that the metering at the connection point should be the one used for such purposes. In the case of the Slovenian demonstrator, submetering is considered to create gaming opportunities for SPs.

Table 6.10: Portfolio vs individual baselining and use of submetering

Demonstrator	Real implementation	
	Individual or portfolio baseline	Submetering for settlement
Northern	Individual	Yes, more accurate settlements
Polish	Individual, it's more accurate and better meet SO needs	No, meters at the connection point where real impact occurs
Cypriot	Individual	Yes
Spanish	Both, aggregated if part of the same network, individual for aggregators	Yes, in the absence of smart-meters
Slovenian	Both	No, due to gaming opportunities
Greek	Individual but aggregated for small units which reduces complexity	Yes, submetering provides real values

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6.4.4 Risk assessment

The demonstrators were asked about the perceived hazard level and probability of the following identified risks for baselines-related topics:

1. Baseline methodology can be a barrier for small resources to participate in flexibility markets
2. Submetering usage for settlement adds significant complexity and requires high costs
3. Self-reported baselines are prompt for gaming by service providers
4. An aggregated baseline can lead to inaccurate flexibility estimation and gaming from service providers

The perceived hazard levels for the identified risk varied among the demonstrators as indicated in Table 6.11, while Table 6.12 shows the probability for the risks related to baseline topics. On average, the baseline methodology is perceived as a barrier for small resources. This is not perceived as a barrier for the Northern demonstrator as the flexibility register could provide baseline if SP cannot do it while in the Greek demonstrator the SO takes that role. The submetering usage for settlement is considered to add significant complexity and requires high costs for most of the demonstrators, again only the Northern demonstrator does not see it as risk. The self-reported baselines are prompt for gaming by service providers is considered as a hazard for all demonstrator except for Slovenia. Finally, all demonstrators considered that aggregated baseline can lead to inaccurate flexibility estimation and gaming from service providers. In this matter, the demonstrators favour individual baselines instead.

Table 6.11: Hazard level for the risks related to baseline topics. The risk levels are colour coded as follows: red – high risk, yellow – mid-level risk, blue – low risk, green – low risk.

Risk	Northern	Polish	Cypriot	Spanish	Slovenian	Greek
1	No	High	Mid	Mid	No	Low
2	No	Mid	Mid	High	High	Not addressed
3	Mid	Mid	High	High	No	Not addressed
4	Mid	Mid	High	Mid	Mid	Not addressed

The probabilities allocated to the abovementioned risks are in line with the hazard identified. The highest probability is allocated to the risk related to aggregated baseline which can lead to inaccurate flexibility estimation and gaming from service providers.

Table 6.12: Probability for the risks related to baseline topics. The risk levels are colour coded as follows: red – high risk, yellow – mid-level risk, blue – low risk, green – low risk.

Risk	Northern	Polish	Cypriot	Spanish	Slovenian	Greek
1	No	High	High	Mid	No	Low
2	No	Mid	High	High	High	Not addressed
3	Mid	Low	High	High	No	Not addressed
4	Mid	Mid	High	Mid	Mid	Not addressed

6.4.5 Recommendations and Best Practices for Harmonising Baselining

SO services and products, SPs' resources and market set ups diverge among the European countries. In such environment, a unique solution for baseline does not fit all. This is recognised by the Draft Proposal for a Network Code on Demand Response jointly submitted to public consultation by the EU DSO Entity and ENTSO-E states [34] states that "depending on the aggregation models applied, the national market design, the type of service and the type of technical resource, different baselining methods can be nationally implemented and applied.

Baselining represents a key element to enable the participation of small resources in the provision of SO services. Although six OneNet demonstrators tested baseline methodologies, the different methodologies were not compared in the same demonstrator with the same conditions. Therefore, it is still soon to draw general conclusions on the performing of one method over another. What is true is that particularities of the SO markets, products and SPs involved can condition the method that better performs in each scenario. Self-reported baselines have been highlighted to encourage gaming by service providers, while baselines imposed by the SO may be seen by SPs as not transparent enough.

Having a flexibility register operator who can not only perform prequalification actions but also baselining can be an enabler for small units to participate in SO markets, as recommended by the Northern demonstrator. On the other hand, submeters can improve baseline calculations but its usage is not widely accepted for the demonstrators, especially for settlement purposes. Guarantees and specifications on submetering authentication and accuracy, in a similar way as current smart meters, could improve its acceptance and avoid gaming possibilities which was perceived as a major risk of baselining methods.

The Draft Proposal for a Network Code on Demand Response also suggests that EU Member States should encourage novel and innovative methods for establishing baseline approaches. This supports the necessity for additional research in creating and evaluating baseline methods that are appropriate for the evolving paradigm of flexibility provision.

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6.5 Market Clearing

6.5.1 Definition of the principles and practices for the design of the market phase

Market clearing is the phase at which the demand and supply are matched to reveal an equilibrium price and quantity. In ideal settings, the sellers bid for their marginal costs, whereas the buyers bid for their marginal benefits. In an electricity market, it might not always be that straightforward as certain non-convexities like start-up cost, divisibility and must-run conditions may affect the simple matching of demand and supply. Hence, the market designs consider the peculiarities of the products and form certain rules to ensure the equilibrium values can be found. In this report, we consider three different aspects of market clearing:

Pricing scheme

A pricing scheme is the rule used for settling the market. The two main pricing schemes used in the market are pay-as-clear and pay-as-bid.

- Pay-as-clear: In this scheme, all market participants are paid at the market clearing price, i.e., the bid price of the marginal unit. The cleared units whose bid prices are below the market clearing price, called inframarginal units, receive an extra payment equal to the difference between the market clearing price and their bid price. This additional income is called the inframarginal revenue. In a competitive market with no market power, the ideal strategy is to bid for the marginal cost of the units such that there is a minimum break-even guarantee if the unit is accepted. The inframarginal revenue, if any, will enable the recovery of capital costs.
- Pay-as-bid: In this scheme, each cleared participant receives the price they bid into the market. Therefore, it is considered discriminatory pricing. In a pay-as-bid system, the same quantity of the product for the same period can have different prices. This prompts the market agent to deviate from their marginal costs and bid for a value higher than their true costs. Furthermore, recovering their capital costs will be challenging if the participant continuously bids for their marginal costs.

Co-optimisation of products

When some services have both availability and activation components, the market rules can define whether these products are procured in a co-optimised manner or in a separate manner.

In a co-optimised procurement, the participant must show availability and activation price in the availability bid. This allows the market operator to calculate the total procurement costs well in advance and mitigate any price volatility close to real-time. On the other hand, for the participants, anticipating the availability price is a challenging task as the opportunity costs are not clear far from real-time. Offering their capacity ahead of time implies that they have to reserve this capacity and abstain from offering it in other energy markets. Accordingly, the payments that they receive from the availability-activation markets should be higher than their opportunity costs of not participating in energy markets. Hence, it represents a risk for the market players.

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In a separate procurement, the risk is transferred to the market operator. The market operator procures capacity (or activation), minimising only the cost of procurement of capacity. At a later stage, close to real-time, the participants bid for the activation component, which is closely related to the opportunity costs of not participating in the energy markets. These prices could be extremely volatile. Close to real-time, the market operator may not have enough flexibility to look for other options. In markets where capacity reservation is a precondition for participation in the activation markets, participants can easily engage in arbitrage opportunities. For a relevant example from the German balancing markets, see [56].

A solution addressing both concerns is to allow free bidding in the activation markets. By procuring enough capacity ahead of time, the system operator can ensure that there would be a minimum quantity of capacity available for use in real-time. Additionally, allowing free bidders (without capacity reservation) increases the competition in the activation market, thereby keeping the gaming opportunities in check.

Transparency of market clearing

The price formation in the market should be clear and simple enough for the market players to understand it. To enable that, markets should publish relevant information, such as clearing prices and volumes. EU regulation 543/2013 establishes the rules related to transparency in the European wholesale markets [61]. It highlights the importance of the availability of complete sets of data for efficient decision-making by the participants, attracting new market players, and increasing the security of energy supplies.

However, the complete availability of market information could also lead to potential gaming attempts. For instance, if a participant realises that they are located at a strategic location, they would use that information for inc-dec gaming[5] in the markets [62], [63]. Hence, increased transparency should be accompanied by stricter market surveillance rules.

6.5.2 Analysis of the demo design for market phases, considering design motivation

In this section, the market-clearing features of different demos are analysed, along with the motivations for their implementation. The data for the analysis is sourced from different OneNet questionnaires and interactions with the demos.

Pricing scheme

Both pay-as-bid and pay-as-clear systems are implemented in OneNet demos, depending on the peculiarities of the local market. Pay-as-bid is slightly more popular than pay-as-clear among the demos, as given in Table 6.13.

[5] Inc-dec gaming refers to the bidding strategy used by agents with units located in proximity to a congested line. The agents try to aggravate congestion by reducing the generation (or increasing the load) in a generation-constrained area and in a later redispatch stage, bid to solve the resulting congestion. Through this strategy, the generators and load receive payments without even producing or consuming energy, and just by arbitraging between the markets.

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Table 6.13: Pricing schemes used by the OneNet demonstrators

Pay-as-bid	Pay-as-clear
Northern	Cyprus
Hungary	Greece (BA)
Greece (local)	
Spain	

In a competitive market, pay-as-clear is advantageous both for market players as well as for market operators. Market participants do not have to mark up their marginal costs to ensure revenue sufficiency, as it is guaranteed by design. Consequently, market operators can clear the market, minimising the total cost of procurement. In a pay-as-bid system, due to the mark-ups made to the marginal costs, the true marginal costs of production (or consumption) are hidden from the market operator. The market operator minimises the bid prices, which may not correspond to the production costs of the unit. As a result, a low-cost unit may not be cleared in the market, while a high-cost unit may be cleared. Furthermore, due to these bid manipulations, the real cost of meeting demand at any given time cannot be interpreted from the market. This means that market clearing may not always be optimal. This is the main motivation for the implementation of a pay-as-clear system in the Cyprus demo.

However, if markets are not competitive, then these arguments may not hold. The basic assumption behind pay-as-clear or uniform pricing is that the products are homogenous (or uniform). When it is not the case, then paying the same price for different prices will not be fair. A good example of that is the congestion management market. The impact of a generator on a generation-abundant node is different from that of one located at a load-intensive node. Hence, depending on the effect of the units on aggravating or relieving the congestion, their remuneration should be different. In such cases, pay-as-bid pricing is relevant. This concept of locational differentiation is the main reason behind the use of pay-as-bid in the Northern demo. In the future, if enough liquidity is available within the same location, the Northern demo might opt for a pay-as-clear system.

The Spanish demo also uses a pay-as-bid system but in their case, it is more related to the path-dependency. The congestion management at the transmission level uses a pay-as-bid system (due to arguments given in the paragraph above). Hence, for comparing the costs of local congestion management with the traditional solutions, the Spanish demo follows the same rules. Similarly, in the Greek demo, there is a mix of pay-as-bid and pay-as-clear systems. This is due to the existing balancing market designs where certain products are settled at pay-as-clear and some others pay-as-bid. However, the Electricity Balancing Guideline (EBGL) specifies the use of pay-as-clear in balancing markets wherever possible [23]. Therefore, in the near future, these markets might choose a pay-as-clear system.

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Co-optimisation of products

The co-optimisation of availability and activation components can reduce the risks associated with resource unavailability close to real-time. The system operator can use the reserved capacity to meet the needs without compromising operational security. On the contrary, separate procurement can allow the market players to represent the real-time value of producing energy rather than an estimated opportunity cost. In markets where separate procurement is in place, free bidding may or may not be allowed.

In theory, allowing free bidding increases the competition and reduces the market power. Both Spanish and Northern demos permit free bidding for this reason. Nevertheless, some peculiarities in the market may require the market regulators to opt for a capacity reservation precondition, i.e., only agents who are cleared in the availability market are permitted to bid in the activation market. Table 6.14 shows the designs opted by the OneNet demos. In the case of the Slovenian demo, the prepayment of the availability bid reduces the high prices of activation energy. Otherwise, the consumers (i.e., the SPs in that case) do not have enough motivation to change their consumption patterns close to real time. For the Cypriot demo, capacity reservation as a precondition allows the system operator to better plan the system operation.

Table 6.14: Demonstrators following the different designs for availability-activation product procurement. The asterisk (*) represents markets in which different products and services use different types of optimisation.

Separate optimisation	Joint optimisation	Free bids allowed	Free bids not allowed
Northern*	Northern*	Northern	Slovenia
Poland	Spain	Poland	Greece
Cyprus	Slovenia	Spain	Cyprus

Transparency of market clearing

Transparency is a necessary quality of the market that facilitates the integration of new market players, enhances the knowledge transfer between agents, and increases market efficiency. However, full transparency of data can also lead to potential gaming opportunities. Table 6.15 shows the type of data published by different OneNet demonstrators.

Table 6.15: The datasets published by different OneNet demos

Demo	Structure of market	Number of sessions	Clearing of markets	Gate closure time	Products traded
Northern*	x	x	x	x	x
Poland					
Slovenia	x	x	x	x	
Hungary	x	x		x	x
Greece			x		x
Cyprus	x	x	x	x	x
Spain	x	x		x	x

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The demos consider that publishing full datasets related to market structure and clearing data has the highest potential for gaming attempts. Mainly in less competitive markets, the participants can see the clearing prices, units, and volumes and come up with strategies to manipulate the prices. In congestion management markets, it could be in the form of inc-dec gaming where the participants deliberately create congestion in one market such that they will be redispatched at a higher price (or pay back less money in the case of a demand) later (ref). Even in a single market setup, if an agent realises that they are the marginal unit, they can raise their bid price really high, affecting the whole procurement.

Again, the gaming concerns and the need for increased transparency depend on the peculiarities of the market. Hence, there is a significant difference in the type of information that demos deem to be fit for publication, as seen in Table 6.15.

6.5.3 Analysis of barriers for market phases harmonisation based on demos' design motivation

There are noticeable differences between the design of local markets between the demos due to the motivations discussed above in Section 6.5.2. The main motivations for the deviations from the recommended designs for harmonisation in terms of pricing scheme, co-optimisation of products and transparency can be grouped as below:

- **Lack of competition**: The gaming concerns are a common theme among the three features analysed in the market clearing section. Pay-as-bid causes concerns related to the unjustified mark-ups, lack of co-optimisation or free bidding causes the concentration of market power and transparency increases the possibility of market manipulation attempts. Competitive markets could reduce these gaming opportunities as the risks involved in those games increase with the number of uncertain factors (i.e. decisions made by other market players). An increased number of market agents also increases the efficiency of market operations and decreases the procurement costs. Due to the novelty of local flexibility markets, the number of SPs participating is still low. Hence, ideal market design principles such as uniform pricing, free bidding, or increased transparency may not be suitable for some demos.
- **Localised needs**: Compared to a wholesale market which is designed for global system needs, local markets are tailored to meet local needs. The services required by a DSO located at one part of the national grid may differ from the ones required by a DSO operating elsewhere. Furthermore, local markets are designed considering the type of distributed generation, the capacity of the grid, type of demand etc. Hence, the design options that a local market uses are suited to the particular environment and may not align with the desirable or recommended options. This is especially relevant when it comes to the market transparency. Different national regulations set different

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levels for transparency. This causes deviations within local market designs across different countries.

- **Operational concerns**: As local flexibility markets are still immature, the SOs may have concerns about the rigidity of the offers. Having capacity reservation conditions as a part of the product co-optimisation (i.e., not allowing free bids in the activation markets) or strict prequalification conditions allows the SOs to better plan their system and reduce the risks of resource inadequacy close to real-time.

6.5.4 Risk assessment

Based on the assessment in Section 6.5.2 and 6.5.3, certain risks could be identified associated to the market clearing harmonisation. These are stated below:

- Risk 1: Increasing the transparency of market clearing and related network information can lead to gaming opportunities
- Risk 2: Lack of coordination among markets may cause operational issues like double activations and give rise to market inefficiencies
- Risk 3: The revenues gained in the market are not sufficiently high to maintain the current participants and attract new players

Table 6.16: summarises the risk levels and their perceived probabilities by different demos analysed. Evidently, revenue insufficiency is considered as the highest risk by almost demos. Five out of eight demos who answered believe that there is a high risk of revenue insufficiency happening in the local markets. In such cases, revenue stacking is a potential solution, as discussed in section 5.3. Instead of SPs depending on just one or two markets for their revenues, they can participate in multiple markets and optimise their bidding between them. Bid forwarding is also an easy way to do this, where instead of the SPs, the market operators can directly forward unused bids from one market to another, maximising the probability of the bid being cleared.

Table 6.16: The risks associated with market clearing with the perceived hazard level and probability. The risk levels are colour coded as follows: red – high risk, yellow – mid-level risk, blue – low risk, green – low risk.

Demo	Risk 1: Increased transparency leads to gaming opportunities		Risk 2: Lack of coordination leading to operational and market inefficiencies		Risk 3: Revenue insufficiency	
	Hazard level	Probability	Hazard level	Probability	Hazard level	Probability
Spain	Low	Low	Mid	Low	Mid	Low
Cyprus	High	High	High	High	High	High

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Czech Republic	Low	Low	Mid	Low	High	Low
Hungary	Low	Low	Low	Mid	High	High
Northern	High	Low	Mid	Low	Mid	High
Poland	Mid	Mid	High	High	High	High
Portugal	Mid	High	Mid	Mid	High	Mid
Slovenia	Mid	Mid	Mid	Mid	High	High

Lack of coordination between different markets and the associated operational risks is perceived to be the next highest risk. Better coordination between SOs is highly relevant to ensure the safe operation of the grid. In this regard, the framework guidelines on demand response (FGDR) emphasises the need for forming SO coordination area, i.e., 'a group of grid elements/users/connection points that may 1) be affected by, 2) providing solutions to, 3) need to provide information to forecast, detect or solve a given congestion or voltage control issue or group of such.' [15]. Within these coordination groups, different levels of coordination could be established. The highest level of coordination shall include at least topics such as a) data exchange, b) grid operation and forecast for grid operation, c) congestion management and voltage control solutions d) network development planning. With the right implementation of these rules, the risk of uncoordinated operations can be mitigated.

The gaming possibilities are perceived to be low-level risks by most demos. In demos like Hungarian, the low-risk level is rationalised by strong regulatory surveillance policies. FGDR mentions that if the publication of data leads to potential gaming issues, then potential mitigation measures should be taken [15]. Such measures include the publication of data in aggregated or anonymous format and the publication of a price range rather than the exact amount.

6.5.5 Recommendations and Best Practices for Harmonising Market Clearing

Based on the analysis of the demo designs and barriers to the harmonisation, the following recommendations could be made.

- **Implementation of pay-as-clear pricing wherever possible**: Pay-as-clear pricing scheme efficiently creates price signals, while ensuring the recovery of capital costs of inframarginal generators. This allows the market agents to bid for their true marginal costs, without engaging in bid manipulations. Hence, adopting a pay-as-clear (or uniform pricing) is beneficial to both agents and market operators. If it is not possible due to reasons such as lack of liquidity, then strict regulatory monitoring mechanisms should be in place.

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- **Timely publication of market results along with regulatory surveillance measures**: As previously discussed, increased market transparency about network impacts could increase gaming concerns. However, transparency enables the potential market players to estimate their likely incomes, making it a non-negotiable feature for the integration of new agents. A possible solution is to combine increased transparency with increased market surveillance to monitor gaming attempts. This could be an ex-ante screening like in the US markets or an ex-post check like in the European wholesale markets .
- **Allow free bidding in activation markets**: In markets without co-optimisation of products (where the price for activation is fixed during capacity reservation), mandatory capacity reservation conditions limit the pool available for the SO to activate close to real-time and can result in very high activation prices. Allowing free bids in the activation markets reduces the market concentration and lowers the activation prices. As seen in the bid forwarding analysis in Section 5.2, free bidding also allows uncleared bids to be transferred to other compatible markets.

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7 Conclusions

This report, within the ambit of the OneNet project, thoroughly examines the harmonisation potential of market-based solutions proposed by the OneNet demonstrators. Through comprehensive analysis, several pivotal insights have emerged in the areas of product harmonisation, market architecture harmonisation, and market phases harmonisation. These insights have shaped key recommendations and best practices, guiding towards a more integrated and harmonised electricity market across EU countries.

Product Harmonisation

Product harmonisation, as explored in this report, is critical in achieving coordinated markets. It enables maximisation of value stacking and efficient allocation of resources, thus enhancing the value of flexibility services. However, product harmonisation is not universally applicable. Its effectiveness hinges on alignment in service types, geographical areas, and market operational processes. The challenges and barriers identified necessitate specific conditions for successful harmonisation, including similar grid structures, mature System Operators (SOs), interoperable ICT systems, and sufficiently liquid and competitive markets.

The analysis of the product harmonisation barrier for OneNet demonstrators led to the formalisation of a set of general recommendations for product harmonisation. It is found that product harmonisation is not a fit-for-all approach; it adds value only when there is an alignment in the type of need or service. This could be the same service, for instance, mFRR services, or similar services, for instance, active power for congestion management and balancing. Moreover, there should also be an alignment in the same geographical area or different areas with similar grid characteristics. Finally, there should be an alignment in market operational processes, i.e., an alignment in market timing and/or some degree of coordination between markets; this could range from an exchange of information to coordination in the form of different TSO-DSO coordination schemes. Product harmonisation can be achieved by harmonising (some) product attributes and/or their values in the different geographical markets where these products would be used. The analysis of demonstrators' choices identified the following requirements to make product harmonisation possible: (i) a similar grid structure and (ii) level of maturity of the SOs, (iii) existing and interoperable ICT systems for data exchange and communication/information, and (iv) a market that is already sufficiently liquid and competitive.

Market Architecture Harmonisation

In the realm of market architecture, our analysis has identified several enablers for effective market coordination. Key recommendations include permitting aggregation in all wholesale markets, allowing free bidding in balancing energy markets, and designing local markets that complement existing wholesale market timings. Additionally, enhancing synergies between local flexibility and intraday markets is crucial for incorporating local resources into wholesale energy markets and enhance value stacking potential for SPs.

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The OneNet demonstrators dealing with market-based coordination are analysed considering the bid forwarding potential between OneNet local markets and wholesale electricity markets. Six cases are detailed described: Poland's local CM capacity to RR markets; Czech Republic's local capacity to intraday markets; Hungary's local capacity to mFRR capacity markets, Hungary's local CM capacity to aFRR energy markets; Spanish local energy to intraday markets, and Finnish local energy to mFRR markets. In cases where bid forwarding from local to central markets is permitted, it is crucial to implement technical procedures to ensure that activating these bids does not disrupt the connecting SO network. Both centralised and decentralised solutions demonstrated in OneNet are valid and can be chosen based on the specific market architecture.

The analysis of market architecture harmonisation potential led to the definition of a set of policy recommendations for market design. Aggregation should be permitted in all markets. Allow free bidding in the balancing energy markets since the capacity reservation condition for balancing markets help the TSOs to procure enough capacity in advance for operational security, but limiting the pool of resources increases the possibilities for gaming. Local market timing should be designed based on the timing of the existing wholesale markets to provide revenue stacking potential for the market players and to maximise the procurement efficiency of the markets. Increase the synergies between the local flexibility and intraday markets since intraday markets trade flexibility at the wholesale level (or transmission level). Hence, these markets are good candidates for incorporating local resources.

Recommendations and Best Practices for Harmonising Prequalification procedures

The harmonisation of market phases, particularly through a common prequalification process, is essential for streamlining operations and promoting market liquidity. This involves balancing the need for dedicated timing and diversification of products, and ensuring coordination among various SOs. The experiences from OneNet project demonstrators offer valuable insights into designing harmonised prequalification procedures that cater to diverse market needs and contexts.

To allow harmonised prequalification procedures, a regulatory framework that is able to adapt itself depending on the necessary adjustments from the field is necessary. Moreover, it seems that prequalification would be more efficient if closer to the trading phase. Harmonised prequalification procedures would be facilitated by a set of harmonised products, as defined by the Table of Equivalence. Harmonised prequalification procedures are also a means to establish more streamlined processes for SPs connected to DSO and TSO networks. Furthermore, further analysis is required to define conditions for new group SP prequalification when some units change. This will help to determine when updates or re-evaluations are necessary without overburdening the system with frequent reassessments. Finally, prequalification procedures should be designed considering scalability, allowing for adaptations to fit various market structures and sizes.

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Recommendations and Best Practices for Harmonising Baselining

This report provides recommendations to support harmonised baselining design among EU countries. These include fostering an environment conducive to the participation of small resources in SO services, exploring innovative baseline methodologies, and establishing a flexibility register operator. The adoption of such measures, as well as continuous research and development in baseline methods, is crucial for adapting to the evolving landscape of flexibility provision. Considering that SO services and products, SPs resources and market setups diverge among the European countries; hence, a unique solution for baseline it is acknowledged that does not fit all. However, it is recommended that a flexibility register operator who can perform prequalification actions and baselining can enable small units to participate in SO markets. On the other hand, submeters can improve baseline calculations but its usage is not widely accepted, especially for settlement purposes. Similar to current smart meters, guarantees and specifications on submetering authentication and accuracy could improve its acceptance. Novel and innovative methods for establishing baseline approaches need additional research in creating and evaluating baseline methods appropriate for the evolving paradigm of flexibility provision.

Recommendations and Best Practices for Harmonising Market clearing

The report also delves into the barriers and challenges to achieving market harmonisation considering market clearing phase. To overcome these, we recommend reducing technical entry barriers to the market, ensuring the timely publication of market results coupled with regulatory surveillance measures, and allowing free bidding in activation markets. These measures are geared towards fostering competition, increasing market transparency, and reducing market concentration.

The analysis of barriers to harmonising market clearing procedures reveals a preference for adopting pay-as-bid solutions over others such as uniform pricing, free bidding, or enhanced transparency. This preference arises from perceived competition limitations. Operational concerns, rooted in a lack of historical data and empirical experience in novel local system service markets, lead to market clearing designs that prioritise solutions mitigating the risks of service supply disruptions. From the examination of demo designs and barriers, formalised recommendations emphasise simplification, transparency, and openness. Market clearing solutions supporting simplified prequalification and aggregation conditions can enhance Service Providers' (SPs) revenue streams. While increased transparency may raise gaming concerns, it is crucial for potential market players to estimate likely incomes, making it an essential feature for integrating new agents. Mandatory capacity reservation conditions can limit the pool available for SOs to activate close to real-time, potentially resulting in high activation prices. Allowing free bids in activation markets serves to reduce market concentration and lower activation prices.

In conclusion, this report underscores the necessity of a harmonised approach to market design, pivotal for the transition to a more integrated and efficient European electricity market. The findings and recommendations herein are instrumental in guiding future endeavours towards achieving this goal.

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

8 References

[1] T. Schittekatte, I. Momber, and L. Meeus, “Future-proof tariff design: Recovering sunk grid costs in a world where consumers are pushing back,” *Energy economics*, vol. 70, pp. 484–498, 2018, doi: https://doi.org/10.1016/j.eneco.2018.01.028

[2] Heymi Bahari and Jehan Sauvagei, “Cross-Border Trade in Electricity and the Development of Renewables-Based Electric Power: Lessons from Europe,” vol. 2013/02, Apr. 2013, doi: https://doi.org/10.1787/18166881. Available: https://www.oecd-ilibrary.org/trade/cross-border-trade-in-electricity-and-the-development-of-renewables-based-electric-power_5k4869cdwnzr-en. [Accessed: Dec. 03, 2023]

[3] EUniversal H2020 project, “EUniversal Deliverable: D5.1 - Identification of relevant market mechanisms for the procurement of flexibility needs and grid services,” EUniversal H2020 project, 2021. Available: https://euniversal.eu/wp-content/uploads/2021/02/EUniversal_D5.1.pdf. [Accessed: Mar. 04, 2021]

[4] S. Bindu, L. Olmos, and J. P. C. Ávila, “Integrating the Central-dispatch Markets into the European Balancing Platforms: Main Lessons Learnt and Challenges,” in *2023 19th International Conference on the European Energy Market (EEM)*, Lappeenranta, Finland: IEEE, Jun. 2023, pp. 1–7. doi: https://doi.org/10.1109/EEM58374.2023.10161745. Available: https://ieeexplore.ieee.org/document/10161745/. [Accessed: Nov. 23, 2023]

[5] OneNet H2020 project, “OneNet Deliverable 3.1 - Overview of market designs for the procurement of system services by DSOs and TSOs,” OneNet H2020 Project, 2021. Available: https://onenet-project.eu/wp-content/uploads/2021/08/D31-Overview-of-market-designs-for-the-procurement-of-system-services-by-DSOs-and-TSOs-1.pdf

[6] INTERRFACE H2020 project, “INTERRFACE Deliverable 5.5 - Single Flexibility Platform Demonstration Description and Results,” Jul. 2022. Available: http://www.interrface.eu/sites/default/files/publications/INTERRFACE_D5.5_vPUBLIC.pdf

[7] Catarina Augusto *et al.*, “BRIDGE Annual report 2021: regulation working group.,” European Commission. Directorate General for Energy., LU, 2023. Available: https://data.europa.eu/doi/10.2833/47621. [Accessed: Nov. 13, 2023]

[8] E. CEDEC, ENTSO-E, E. GEODE, “TSO-DSO Report-An Integrated Approach to Active System Management,” 2019. Available: https://docstore.entsoe.eu/Documents/Publications/Position%20papers%20and%20reports/TSO-DSO_ASM_2019_190416.pdf. [Accessed: Dec. 07, 2020]

[9] OneNet Project, “OneNet Deliverable D2.2 - A set of standardised products for system services in the TSO-DSO-consumer value chain,” 2021. Available: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5df2250da&appId=PPGMS

[10] CoordiNet project, “CoordiNet Deliverable D6.7 – Roadmap towards a new market design including the implementation of standardised products for system services,” 2022. Available: https://private.coordinet-project.eu//files/documentos/62cc7568dcddfCOORDINET_WP6_D%206.7_ROADMAP%20TOWARDS%20A%20NEW%20MARKET%20DESIGN%20_V1.0_06.07.22.pdf

[11] CEDEC, EDSO, ENTSO-E, Eurelectric, and GEODE, “TSO-DSO Data Management Report,” 2016. Available: https://www.entsoe.eu/2016/07/27/tso-dso-data-management-report/

[12] ENTSO-E, “Review of flexibility platforms,” 2021. Available: https://eepublicdownloads.azureedge.net/clean-documents/SOC%20documents/SOC%20Reports/210957_entso-e_report_neutral_design_flexibility_platforms_04.pdf

[13] S. Bindu, M. Troncia, J. P. C. Ávila, and A. Sanjab, “Bid Forwarding as a Way to Connect Sequential Markets: Opportunities and Barriers,” presented at The International Conference on European Energy Markets (EEM), Lappeenranta, Finland: IEEE, 2023. doi: https://doi.org/10.1109/EEM58374.2023.10161855

[14] A. Sanjab *et al.*, “OneNet Deliverable D3.3 - Recommendations for Consumer-Centric Products and Efficient Market Design,” OneNet H2020 Project, 2023. Available: https://onenet-project.eu/wp-content/uploads/2023/11/OneNet_D3.3_V1.0.pdf

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

[15] ACER, "Framework Guideline on Demand Response," 2022. Available: https://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Framework_Guidelines/Framework%20Guidelines/FG_DemandResponse.pdf
[16] M. Troncia, J. P. Chaves Ávila, C. Damas Silva, H. Gerard, and G. Willeghems, "Market-Based TSO–DSO Coordination: A Comprehensive Theoretical Market Framework and Lessons from Real-World Implementations," *Energies*, vol. 16, no. 19, p. 6939, Oct. 2023, doi: https://doi.org/10.3390/en16196939
[17] OMIE, "Details of the Intraday Market 's Operation," 2020. Available: https://www.omie.es/sites/default/files/inline-files/intraday_and_continuous_markets.pdf. [Accessed: Dec. 10, 2021]
[18] Nordic mFRR EAM project, "mFRR energy activation market: BSP - Implementation Guide." Sep. 09, 2021. Available: https://nordicbalancingmodel.net/wp-content/uploads/2021/09/Implementation-Guide-mFRR-energy-activation-market-BSP.pdf. [Accessed: Aug. 03, 2023]
[19] Fingrid, "Terms and conditions for providers of Manual Frequency Restoration Reserves (mFRR)." 2022. Available: https://www.fingrid.fi/globalassets/dokumentit/en/electricity-market/reserves/en-liite-1-ehdot-ja-edellytykset-manuaalisen-taajuudenpalautusreservin-mfrr-toimittajalle_en2-id-379429.pdf. [Accessed: Sep. 03, 2023]
[20] Helena Gerard, José Pablo Chaves Avila, Karine Laffont-Eloire, and Katerina Drivakou, "BRIDGE Annual report 2022: regulation working group.," 2022. Available: https://op.europa.eu/en/publication-detail/-/publication/26e32453-31ac-11ee-946a-01aa75ed71a1/language-en/format-PDF/source-294272965
[21] D. Stampatori *et al.*, "Recommendations for customer engagement strategies. OneNet D11.5," 2023. Available: https://onenet-project.eu/wp-content/uploads/2023/07/OneNet-Deliverable-D11.5_v1.0.pdf
[22] European Parliament, *DIRECTIVE (EU) 2019/ 944 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL - of 5 June 2019 - on common rules for the internal market for electricity and amending Directive 2012/ 27/ EU*, vol. 2019/944. 2019, p. 75. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019L0944
[23] European Commission, "Commission Regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity balancing (Text with EEA relevance.)," Brussels, 2017/2195, 2017. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32017R2195. [Accessed: Oct. 08, 2023]
[24] European Commission, *COMMISSION REGULATION (EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management*. 2015. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02015R1222-20210315
[25] European Parliament and Council of the European Union, *Regulation no 714/2009 of the European parliament and of the council of 13 July 2009 on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003*. 2009. Available: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:211:0015:0035:EN:PDF
[26] EUDSO Entity and ENTSO-E, "Draft Proposal for a Network Code on Demand Response - version for public consultation," 2023. Available: https://consultations.entsoe.eu/markets/public-consultation-networkcode-demand-response/supporting_documents/Network%20Code%20Demand%20Response%20v1%20draft%20proposal.pdf
[27] B. Battke, T. S. Schmidt, D. Grosspietsch, and V. H. Hoffmann, "A review and probabilistic model of lifecycle costs of stationary batteries in multiple applications," *Renewable and Sustainable Energy Reviews*, vol. 25, pp. 240–250, Sep. 2013, doi: https://doi.org/10.1016/j.rser.2013.04.023
[28] M. Merten, C. Olk, I. Schoeneberger, and D. U. Sauer, "Bidding strategy for battery storage systems in the secondary control reserve market," *Applied Energy*, vol. 268, p. 114951, Jun. 2020, doi: https://doi.org/10.1016/j.apenergy.2020.114951
[29] J. M. Schwidtal, M. Agostini, M. Coppo, F. Bignucolo, and A. Lorenzoni, "Optimized operation of distributed energy resources: The opportunities of value stacking for Power-to-Gas aggregated with PV," *Applied Energy*, vol. 334, p. 120646, Mar. 2023, doi: https://doi.org/10.1016/j.apenergy.2023.120646
[30] Comisión Nacional de los Mercados y la Competencia, *Resolución de 17 de marzo de 2022, de la Comisión Nacional de los Mercados y la Competencia, por la que se aprueban los procedimientos de operación adaptados a la programación cuarto-horaria de la operación del sistema eléctrico peninsular español.*

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

«BOE» núm. 75, de 29 de marzo de 2022, páginas 41169 a 41351 (183 págs.). 2022. Available: https://www.boe.es/eli/es/res/2022/03/17/(3)
[31] D. Stølsbotn, "Trading in NorFlex 2020-22: NODES White Paper," Oslo, 2022. Available: https://nodesmarket.com/publications/
[32] N. Etherden and Y. Ruwaida, "CoordiNet Deliverable D4.1 - Site Specific Product Portfolio to Be Used in Swedish Demo (Including Contracts, Routines and Business Models)," 2020. Available: https://private.coordinet-project.eu/files/documentos/60379e43b9d9aD4.1%20products%20in%20the%20Swedish%20demo%20 2020-12-21.pdf
[33] OneNet Project, "OneNet Deliverable D3.4 - Regulatory and demo assessment of proposed integrated markets," 2023. Available: https://onenet-project.eu/wp-content/uploads/2023/09/OneNet_D3.4_V1.0.pdf
[34] EUDSO Entity and ENTSO-E, "Draft Proposal for a Network Code on Demand Response - version for public consultation," 2023. Available: https://consultations.entsoe.eu/markets/public-consultation-networkcode-demand-response/supporting_documents/Network%20Code%20Demand%20Response%20v1%20draft%20proposal.pdf
[35] European Commission, *Directive (Eu) 2019/944 Of The European Parliament And Of The Council - of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast)*. 2019. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019L0944
[36] OneNet Project, "OneNet Deliverable D3.2 - Definition of integrated and fully coordinated markets for the procurement of grid services by DSOs and TSOs," H2020 OneNet project D3.2, 2023. Available: https://onenet-project.eu/wp-content/uploads/2023/04/D3.2_OneNet_v1.0.pdf. [Accessed: Oct. 08, 2023]
[37] CEDEC, E.DSO, ENTSO-E, Eurelectric, GEODE, "TSO-DSO Roadmap on Distributed Flexibility," 2022. Available: https://www.geode-eu.org/wp-content/uploads/2021/07/210728_TSO-DSO-Roadmap-on-Distributed-Flexibility.pdf
[38] J. P. Chaves Ávila, M. Troncia, C. D. Silva, and G. Willeghems, "OneNet Deliverable D3.1 - Overview of market designs for the procurement of system services by DSOs and TSOs," 2021. Available: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5df2250db&appId=PPGMS. [Accessed: Aug. 03, 2023]
[39] J. P. Chaves Ávila, M. Troncia, B. Alonso, and C. Vidal, "OneNet Deliverable D9.6 - Demo results assessment and data collection report – Spain D9.6," OneNet H2020 Project, 2023. Available: https://onenet-project.eu/wp-content/uploads/2023/08/OneNet_D9.6_v1.0.pdf
[40] B. Alonso Santos *et al.*, "OneNet Deliverable D9.3 - Validation and results of concept test - Spain D9.3," OneNet H2020 Project, 2023. Available: https://onenet-project.eu/wp-content/uploads/2023/05/OneNet_D9.3_v1.0.pdf
[41] Á. Baldauf *et al.*, "OneNet Deliverable D10.4 - Report on demonstrations D10.4," 2023. Available: https://onenet-project.eu/wp-content/uploads/2023/10/OneNet_D10.4_V1.0.pdf
[42] OneNet Project, "OneNet Deliverable D10.2 - Report on selection of services," 2022. Available: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5ea0018ce&appId=PPGMS
[43] N. Suljanović, A. Dervišević, and D. Falkowski, "OneNet Deliverable D10.3 - Report on development of integral market platform D10.3," OneNet H2020 Project, 2020. Available: https://onenet-project.eu/wp-content/uploads/2023/03/OneNet-D10-3_final.pdf
[44] A. Seitsamo, M. Löf, H. Juhlin, J. Rinta-Luoma, K. Kukk, and I. Zikmanis, "OneNet Deliverable D7.1 - Report on Flexibility Availability D7.1," OneNet H2020 Project, 2020. Available: https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5ecdb2bd7&appId=PPGMS
[45] J. Rinta-Luoma *et al.*, "OneNet Deliverable D7.2 - Flexibility register description and implementation D7.2," OneNet H2020 Project, 2023. Available: https://onenet-project.eu/wp-content/uploads/2023/10/D7.2_OneNet_v1.0.pdf

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

[46] A. A. Bashir *et al.*, “OneNet Deliverable D7.3 - Report on market functionality D7.3,” OneNet H2020 Project, 2023. Available: https://onenet-project.eu/wp-content/uploads/2023/05/OneNet_D7.3_v1.0-1.pdf
[47] K. Kukk, E.-K. Gildemann, A. Sanjab, L. Marques, T. Treumann, and M. Petron, “OneNet Deliverable D7.4 - Northern Cluster Demonstrator: TSO-DSO Coordination module description and implementation D7.4,” OneNet H2020 Project, 2022. Available: https://onenet-project.eu/wp-content/uploads/2022/12/OneNet_D7.4_v.1.0.pdf
[48] I. Vaitiekutė, E. Drungienė, and P. Lūsis, “OneNet Deliverable D7.5 - Report on DSO & TSO value generation drivers D7.5,” OneNet H2020 Project, 2023. Available: https://onenet-project.eu/wp-content/uploads/2023/10/OneNet_D7.5_V1.0.pdf
[49] ENTSO-E, “Balancing Report 2020,” 2020. Available: https://www.entsoe.eu/news/2020/06/30/2020-entso-e-market-reports/
[50] ENTSO-E, “ENTSO-E Balancing report 2022,” 2022. Available: https://eepublicdownloads.entsoe.eu/clean-documents/nc-tasks/2022_ENTSO_E_Balancing_Report_Web_2bddb9ad4f.pdf. [Accessed: Jul. 04, 2022]
[51] PSE S.A, “PSE S.A. report on balancing pursuant to Article of Commission Regulation60 (EU) 2017/2195 of November23 2017 establishing guidelines for balancing.” 2020. Available: https://www.pse.pl/documents/20182/dad9e256-4357-485b-a3c2-cbfd578e7d8c
[52] ENTSO-E, “Single Intraday Coupling (SIDC),” 2023. Available: https://www.entsoe.eu/network_codes/cacm/implementation/sidc/. [Accessed: Dec. 14, 2021]
[53] L. Paizs, “Electricity Pricing and Market Power: Evidence from the Hungarian Balancing Energy Market,” in *Engineering and Industry*, D. Raisz, Ed., Trivent Publishing, 2015. doi: https://doi.org/10.22618/TP.EI.20151.192003. Available: http://trivent-publishing.eu/pdfdownload/3.LaszloPaizs.pdf. [Accessed: Nov. 09, 2023]
[54] S. Bindu, J. P. Chaves Ávila, and L. Olmos, “Factors Affecting Market Participant Decision Making in the Spanish Intraday Electricity Market: Auctions vs. Continuous Trading,” *Energies*, vol. 16, no. 13, p. 5106, Jul. 2023, doi: https://doi.org/10.3390/en16135106
[55] Fingrid, “Terms and conditions for providers of Manual Frequency Restoration Reserves (mFRR).” Available: https://www.fingrid.fi/globalassets/dokumentit/en/electricity-market/reserves/en-liite-1-ehdot-ja-edellytykset-manuaalisen-taajuudenpalautusreservin-mfrr-toimittajalle_en2-id-379429.pdf. [Accessed: Sep. 03, 2023]
[56] K. Poplavskaya, J. Lago, S. Strömer, and L. de Vries, “Making the most of short-term flexibility in the balancing market: Opportunities and challenges of voluntary bids in the new balancing market design,” *Energy Policy*, vol. 158, p. 112522, Nov. 2021, doi: https://doi.org/10.1016/J.ENPOL.2021.112522
[57] Emmanouil Zoulias, Nenad Sijakovic, Aleksandar Terzic, Vladan Ristic, Dimitra Makrygiorgou, and Christos Christodoulou, “OneNet Deliverable D8.2: Development and implementation of the ‘F-Channel’ platform - D8.2,” OneNet H2020 Project, 2023. Available: https://onenet-project.eu/wp-content/uploads/2023/10/OneNet_D8.2_V1.0.pdf
[58] M. Lacerda *et al.*, “OneNet Deliverable D9.2 - Validation and results of concept test - Portugal D9.2,” 2023. Available: https://onenet-project.eu/wp-content/uploads/2023/05/OneNet_D9.2_v1.0.pdf
[59] L. Lind, J. P. Chaves-Ávila, O. Valarezo, A. Sanjab, and L. Olmos, “Baseline methods for distributed flexibility in power systems considering resource, market, and product characteristics,” *Utilities Policy*, vol. 86, p. 101688, Feb. 2024, doi: https://doi.org/10.1016/j.jup.2023.101688
[60] I. A. Campodonico Avendano, F. Dadras Javan, B. Najafi, A. Moazami, and F. Rinaldi, “Assessing the impact of employing machine learning-based baseline load prediction pipelines with sliding-window training scheme on offered flexibility estimation for different building categories,” *Energy and Buildings*, vol. 294, p. 113217, Sep. 2023, doi: https://doi.org/10.1016/j.enbuild.2023.113217
[61] European Commission, *Commission Regulation (EU) No 543/2013 of 14 June 2013 on submission and publication of data in electricity markets and amending Annex I to Regulation (EC) No 714/2009 of the European Parliament and of the Council Text with EEA relevance*, vol. 163. 2013. Available: http://data.europa.eu/eli/reg/2013/543/oj/eng. [Accessed: Nov. 28, 2023]
[62] E. Beckstedde, L. Meeus, and E. Delarue, “A bilevel model to study inc-dec games at the TSO-DSO interface,” *Policy and Regulation IEEE Transactions on Energy Markets*, pp. 1–10, 2023, doi: https://doi.org/10.1109/TEMPR.2023.3292425

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

[63] L. Hirth and I. Schlecht, “Market-Based Redispatch in Zonal Electricity Markets: The Preconditions for and Consequence of Inc-Dec Gaming,” 2020. Available: https://www.econstor.eu/bitstream/10419/222925/1/Market-Based%20Redispatch%20in%20Zonal%20Electricity%20Markets.pdf. [Accessed: Sep. 20, 2021]

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

9 Appendix

9.1 Overview of OneNet harmonised products used by the demos

Table 9.1: Overview corrective local active product

Attribute	Harmonised OneNet product attribute value [9]	Northern demo – NRT-P-E (Near Real-Time-Active Energy)	Cyprus – Change of active power	Cyprus – Phase balancing (this product is also used as a corrective local reactive product)	France – Near Real Time corrective local active energy	Spain	Slovenia
Capacity/energy	Capacity, energy or both	Energy	Both	Both	Energy	Energy	Capacity -> 20kw of flexibility
Location required (Y/N)	Yes	Y	Y	Y	Y	Y	Yes
Maximum full activation time	<60 min	≤12.5 min	60s	60s	Not considered	<60 min	15 min
Minimum required duration of delivery period	A multiple of 15 minutes up to 1 hour	5 min	1 h	1 h	Not considered	A multiple of 15 minutes up to 1 hour	15 min
Maximum deactivation period	Defined in terms and conditions for SPs	≤10 min	60 s	60 s	Not considered	Defined in terms and conditions for SPs	Not defined
Maximum recovery period	Defined in terms and conditions for SPs	NA	1 h	1 h	Not considered	Defined in terms and conditions for SPs	2h
Maximum number of activations (per day, week…)	/	NA	/	/	Not considered	1	2 per day
Required mode of activation	Automatic or manual (if compliant with FAT)	Manual	Manual	Manual	Not considered	Automatic or manual (if compliant with FAT)	Not defined
Minimum quantity	1 MW for TSOs 0.01 MW for DSOs	0.01…1 MW	0.01 MWh	$0.01MVA^{-1}$ or MVA^{0}	Not considered	1 MW for TSOs 0.01 MW for DSOs	Not defined
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed	Y accepted	Y accepted	N	Not considered	Divisible and indivisible bids are allowed	Y, allowed
Granularity	1 MW for TSOs 0.01 MW for DSOs	0.01…1 MW	0.01 MWh	$0.01MVA^{-1}$ or MVA^{0}	Not considered	1 MW for TSOs 0.01 MW for DSOs	N
Maximum and minimum price	N/A	N/A	It will be based on the market clearing	It will be based on the market clearing	Not considered	Depending on the magnitude and duration of the problem to be solved (approx. > 2000 euro)	Not defined
Availability price (Y/N)	If required, in €/MW	N	Y	Y	N	N	N
Activation price (Y/N)	Yes, in €/MWh	Y	Y	Y	N	Yes, in €/MWh	0,6 €/kWh
Symmetric/asymmetric product (Y/N)	No symmetry required	Asymmetric	Y	Y	Not considered	No symmetry required	Asymmetric
Aggregation allowed (Y/N)	Allowed	Y	Y	N	Not considered	Allowed	Yes

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Table 9.2: Overview predictive short-term local active product

Attribute	Harmonised OneNet product attribute value [9]	Northern demo – ST-P-E (Short-term active energy)	Northern demo – ST-P-C (Short-term active capacity	Spain	Hungary - Change in active power (P) (CM & VC)	Greece - Predictive congestion management for TSO/DSO product	Poland - Change in active power (P) (CM & VC)	Portugal - Products for Intraday Congestion Management for DSO/TSO	Portugal - Products for Day-Ahead Congestion Management for DSO/TSO	Czech Republic - Local congestion management of active power
Capacity/energy	Capacity, energy or both	Energy	Capacity	Energy, Capacity+ Energy	Capacity + energy	Energy	Energy	Not considered	Not considered	Not considered
Location required (Y/N)	Yes	Y	Y	Y	Y	Y	Y	Considered	Considered	Not considered
Maximum full activation time	<60 min	2 h	≤12.5 min	<60 min	NA	60min	1 h	Considered	Considered	Not considered
Minimum required duration of delivery period	A multiple of 15 minutes up to 1 hour	1 h	15 min	A multiple of 15 minutes up to 1 hour	60 min	15 min	NA	Not considered	Not considered	Not considered
Maximum deactivation period	Defined in terms and conditions for SPs	NA	5 min	Defined in terms and conditions for SPs	NA	Defined in terms and conditions for SPs	NA	Not considered	Not considered	Not considered
Maximum recovery period	Defined in terms and conditions for SPs	NA	≤10 min	Defined in terms and conditions for SPs	NA	Defined in terms and conditions for SPs	NA	Not considered	Not considered	Not considered
Maximum number of activations (per day, week…)	/	NA	NA	1	NA	Defined in terms and conditions for SPs	NA	Not considered	Not considered	Not considered
Required mode of activation	Automatic or manual (if compliant with FAT)	Manual	Manual	Automatic or manual (if compliant with FAT)	manual	Manual (setpoint)	NA	Considered	Considered	Not considered
Minimum quantity	1 MW for TSOs 0.01 MW for DSOs	0.1 MW	0.01…1 MW	1 MW for TSOs 0.01 MW for DSOs	0.1 kW	1 MW	NA	Not considered	Not considered	Not considered
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed	Y accepted	Y accepted	Divisible and indivisible bids are allowed	Y accepted	N	Y	Not considered	Not considered	Not considered
Granularity	1 MW for TSOs 0.01 MW for DSOs	0.01 MW	0.01…1 MW	1 MW for TSOs 0.01 MW for DSOs	0.1 kW	0.1 MW	1 kW	Not considered	Not considered	Not considered
Maximum and minimum price	/	+/- 9999 €/MWh	NA or defined in the tender	Depending on the problem to be solved	0 … 3000 EUR/MWh (– equivalent in local currency)	/	NA	Not considered	Not considered	Not considered
Availability price (Y/N)	If required, in €/MW	N	Y	If required, in €/MW	N	N	N	Not considered	Not considered	Not considered
Activation price (Y/N)	Yes, in €/MWh	Y	N	If required, in €/MWh	Y	Y	Y	Not considered	Not considered	Not considered

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Symmetric/asymmetric product (Y/N)	No symmetry required	Asymmetric	Asymmetric	No symmetry required	N (asymmetric)	N	NA	Not considered	Not considered	Not considered
Aggregation allowed (Y/N)	Allowed	Y	Y	Y	N	Y	Y	Considered	Considered	Not considered

Table 9.3: Overview predictive long-term local active product

Attribute	Harmonised OneNet product attribute value [9]	Northern demo – Long-term active capacity/energy (LT-P-C/E	Spain	Portugal – Sustain	Portugal – Secure	Greece – severe state prevention/restoration
Capacity/energy	Capacity, Energy or both	Capacity	Capacity, capacity + energy	Not considered	Not considered	Energy
Location required (Y/N)	Yes	Yes	Yes	Considered	Considered	Y
Maximum full activation time	24h	3 h	24h	Considered	Considered	24h
Minimum required duration of delivery period	A multiple of 15 minutes up to 1 hour	1 h	A multiple of 15 minutes up to 1 hour	Not considered	Not considered	15 min
Maximum deactivation period	Defined in terms and conditions for SPs	1 h	Defined in terms and conditions for SPs	Not considered	Not considered	/
Maximum recovery period	Defined in terms and conditions for SPs	Defined in tender --> can be different from one SO to another	Defined in terms and conditions for SPs	Not considered	Not considered	/
Maximum number of activations (per day, week…)	/	Defined in tender	As contracted	Not considered	Not considered	/
Required mode of activation	Automatic/ Manual	Manual	Automatic or manual (if compliant with FAT)	Considered	Considered	Manual
Minimum quantity	1 MW for TSOs 0.01 for DSOs	0.1 MW	1 MW for TSOs 0.01 for DSOs	Not considered	Not considered	1 MW
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed	Y accepted	Divisible and indivisible bids are allowed	Not considered	Not considered	N
Granularity	1 MW for TSOs 0.01 for DSOs	0.001 MW	1 MW for TSOs 0.01 for DSOs	Not considered	Not considered	1 MW
Maximum price	/	Defined in tender	It depends on the cost of the traditional grid reinforcement	Not considered	Not considered	/
Availability price (Y/N)	If required, in €/MWh	Y	in €/MW	Not considered	Not considered	/
Activation price (Y/N)	If required, in €/MWh	Y	If required, in €/MWh	Not considered	Not considered	/
Symmetric/asymmetric product (Y/N)	No symmetry required	Asymmetric	No symmetry required	Not considered	Not considered	N
Aggregation allowed (Y/N)	Allowed	Y	Allowed	Considered	Considered	Y

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Table 9.4: Overview corrective local reactive product

Attribute	Harmonised OneNet product attribute value [9]	Cyprus - Change of reactive power	Cyprus - Phase balancing	Greece - Reactive support
Capacity/energy	Capacity, Energy or both	Both	Both	Energy
Location required (Y/N)	Yes	Y	Y	Y
Maximum full activation time	<60 min	60s	60s	60min
Minimum required duration of delivery period	A multiple of 15 minutes up to 1 hour	1 h	1 h	15min
Maximum deactivation period	Defined in terms and conditions for SPs	60 s	60 s	Defined in terms and conditions for SPs
Maximum recovery period	Defined in terms and conditions for SPs	1 h	1 h	Defined in terms and conditions for SPs
Maximum number of activations (per day, week…)	/	/	/	Defined in terms and conditions for SPs
Required mode of activation	Automatic or manual (if compliant with FAT)	Manual	Manual	Manual (setpoint)
Minimum quantity	0.01 Mvar or 0.1 Mvar	0.01 Mvarh	0.01MVA^{-1} or MVA^{0}	0.1 MVar
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed	Y accepted	N	N
Granularity	0.01 MVar	0.01 Mvarh	0.01MVA^{-1} or MVA^{0}	/
Maximum and minimum price	/	It will be based on the market clearing	It will be based on the market clearing	/
Availability price (Y/N)	If required, in €/MVar	Y	Y	N
Activation price (Y/N)	Yes, in €/MVarh	Y	Y	Y
Symmetric/asymmetric product (Y/N)	No symmetry required	Y	Y	N
Aggregation allowed (Y/N)	Allowed	Y	N	Y

Table 9.5: Overview predictive short-term local reactive product

Attribute	Harmonised OneNet product attribute value [9]	Hungary - Change in active power (Q) (CM & VC)
Capacity/energy	Capacity, Energy or both	NA
Location required (Y/N)	Yes	NA
Maximum full activation time	<60 min	NA
Minimum required duration of delivery period	A multiple of 15 minutes up to 1 hour	NA
Maximum deactivation period	Defined in terms and conditions for SPs	NA
Maximum recovery period	Defined in terms and conditions for SPs	N/A
Maximum number of activations (per day, week…)	/	N/A
Required mode of activation	Manual/ Automatic	NA
Minimum quantity	0.01 MVar or 0.1 MVar	NA
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed	NA
Granularity	0.01 MVar	NA

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Maximum and minimum price		NA
Availability price (Y/N)	If required, in €/MVar	NA
Activation price (Y/N)	If required, in €/MVarh	NA
Symmetric/asymmetric product (Y/N)	No symmetry required	NA
Aggregation allowed (Y/N)	Allowed	NA

Table 9.6: Overview predictive long-term local reactive product

Attribute	Harmonised OneNet product attribute value [9]	Czech Republic -Voltage Control by Q management/ Reactive Power Management
Capacity/energy	Capacity, Energy or both	NA
Location required (Y/N)	Yes	NA
Maximum full activation time	24h	NA
Minimum required duration of delivery period	A multiple of 15 minutes up to 1 hour	NA
Maximum deactivation period	Defined in terms and conditions for SPs	NA
Maximum recovery period	Defined in terms and conditions for SPs	NA
Maximum number of activations (per day, week…)	/	NA
Required mode of activation	Automatic/Manual	NA
Minimum quantity	0.01 MVar or 0.1 MVar	NA
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed	NA
Granularity	0.01 MVar	NA
Maximum and minimum price	/	NA
Availability price (Y/N)	If required, in €/MVar	NA
Activation price (Y/N)	If required, in €/MVarh	NA
Symmetric/asymmetric product (Y/N)	No symmetry required	NA
Aggregation allowed (Y/N)	Allowed	NA

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9.2 Theoretical market framework tables for the analysed demonstrators

9.2.1 Theoretical market framework tables for the Spanish demonstrator

Table 9.7: Description of the 'Entire market architecture' pillar using the Theoretical Market Framework for the OneNet Spanish demo

Feature	Sub-feature	ESP: LT-D-P-A	ESP: LT-D-P-AE	ESP: ST-D-P-E	ESP: RT-D-P-E	Additional Information
Submarkets	**Number of submarkets**	4				
	Gate Opening Time (GOT)	From months to weeks ahead	From months to weeks ahead	Day-ahead or the next hour after the DSO request (limit 11 pm)	The day of delivery Next hour market for **intraday** service	
	Gate Closure Time (GCT)	2 days before activation time	2 days before activation time	Day-ahead Day ahead market closes at 14:00 for the day ahead product or next hour market for intraday service	Near Real time	
	Market Time Unit (MTU)	1 hour	1 hour	1 hour	1 hour	quarter of hour is under consideration
	Sub-market type	Auction market	Auction market	Auction market	Auction market	
Services	**Service**	Congestion management	Congestion management	Congestion management	Congestion management	
Product	**Type of product**	Active power Availability	Active power Availability Active power Availability and activation	Active Power Activation Active power Availability (optional)	Active Power Activation	
	OneNet Harmonised product acquired	Predictive long-term local active	Predictive long-term local active	Predictive short-term local active	Corrective local active	
	Technical requirements	As defined for Predictive long-term local active	As defined for Predictive long-term local active	As defined for Predictive short-term local active	As defined for Corrective local active	See section 4.2 and [9]
Location	**Level of spatial granularity**	Distribution system areas	Distribution system areas	Distribution system areas	Distribution system areas	Two kinds of areas are considered: Basic areas are a single postal code. Aggregated areas combine basic areas according to DSOs' needs.
	Responsible System Operator	DSO	DSO	DSO	DSO	
	Voltage Level where resources are located	MV, LV	MV, LV	MV, LV	MV, LV	
Market Roles and actors	**Who is the buyer(s)**	DSO	DSO	DSO	DSO	
	Who is the seller(s)	SP unit and Group	SP unit and Group	SP unit and Group	SP unit and Group	
	Allowed technologies (Generators, Loads, Storage)	Generators, Loads, Storage	Generators, Loads, Storage	Generators, Loads, Storage	Generators, Loads, Storage	
	Aggregation method	Area	Area	Area	Area	
	Aggregation mix allowed	All technologies, but upward and downward flexibility cannot be aggregated in the same bid	All technologies, but upward and downward flexibility cannot be aggregated in the same bid	All technologies, but upward and downward flexibility cannot be aggregated in the same bid	All technologies, but upward and downward flexibility cannot be aggregated in the same bid	
	Who is the MO	IMO	IMO	IMO	IMO	
	Participation in submarket	Optional	Optional	Hybrid	Optional	

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Table 9.8: Description of the 'Sub-market coordination' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Spanish demo

Feature	Sub-feature	ESP: LT-D-P-A	ESP: LT-D-P-AE	ESP: ST-D-P-E	ESP: RT-D-P-E	Additional Information
Allocation principle of flexibility	**System operators order**	Exclusivity for DSO	Exclusivity for DSO	Exclusivity for DSO	Exclusivity for DSO	
	TSO access to DERs	Not applicable	Not applicable	Not applicable	Not applicable	
	Commitment to bid selection	Not Applicable	Not Applicable	From LT-D-P-A: Conditional From LT-D-P-AE: Conditional	Not Applicable	Participation forwarding based on the condition established in the availability bid
	Forwarding of bids	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Bid forwarding from ST-D-P-E to intraday energy auction has been conceptually investigated
Timeframe for coordination	**Market phase for coordination between submarkets**	With ST-D-P-E: Procurement	With ST-D-P-E: Procurement	With LT-D-P-A: Procurement With LT-D-P-AE: Procurement	Not Applicable	

Table 9.9: Description of the 'Market optimisation' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Spanish demo

Feature	ESP: LT-D-P-A	ESP: LT-D-P-AE	ESP: ST-D-P-E	ESP: RT-D-P-E	Additional Information
Market optimisation	Decentralised	Decentralised	Decentralised	Decentralised	
Submarkets optimisation strategy	Sequential	Sequential	Sequential	Sequential	
Sub-market clearing objective	Minimisation of cost	Minimisation of cost	Minimisation of cost	Minimisation of cost	

Table 9.10: Description of the 'Market operation' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Spanish demo

Feature	Sub-feature	ESP: LT-D-P-A	ESP: LT-D-P-AE	ESP: ST-D-P-E	ESP: RT-D-P-E	Additional Information
Remuneration scheme		Auctions pay-as-bid.	Auctions pay-as-bid.	Auctions pay-as-bid.	Auctions pay-as-bid.	
Remunerated product attribute		Active power Availability	Active power Availability Active power availability and activation	Active Power Availability Active Power Activation	Active Power Activation	
Market clearing type		Discrete	Discrete	Discrete	Discrete	
Procurement frequency		Event-based on DSO call	Event-based on DSO call	Event-based on DSO call	Event-based on DSO call	
Bid properties	**Minimum bid size**	10 kW	10 kW	10 kW	10 kW	
	Bid structure	Simple	Simple	Simple	Simple	

Table 9.11: Description of the 'Network representation' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Spanish demo

Feature	ESP: LT-D-P-A	ESP: LT-D-P-AE	ESP: ST-D-P-E	ESP: RT-D-P-E	Additional Information
Representation of network constraints	Comprehensive grid data; Partial grid data	Comprehensive grid data; Partial grid data	Comprehensive grid data; Partial grid data	Comprehensive grid data; Partial grid data	
Timing of the inclusion of network constraints	Definition of procurement areas Procurement phase	Definition of procurement areas Procurement phase	Definition of procurement areas Procurement phase	Definition of procurement areas Procurement phase	

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9.2.2 Theoretical market framework tables for the Polish demonstrator

Table 9.12: Description of the 'Entire market architecture' pillar using the Theoretical Market Framework for the OneNet Polish demo

Feature	Sub-feature	POL: MT-D-P-A	POL: DA-D-P-E	Additional Information
Submarkets	**Number of submarkets**	2		Two separated markets, one for availability (capacity) and one for activation (energy) is motivated by the need of covering different time horizons in which the service will be obtained. The day-ahead market procures energy since closer to the time of delivery, for a longer time horizon and the lack of certainty whether a given service will be necessary within a week(s) makes safer to purchase capacity first
	Gate Opening Time (GOT)	Weeks ahead	Day-ahead	
	Gate Closure Time (GCT)	Weeks ahead	Day-ahead	
	Market Time Unit (MTU)	1 hour	1 hour	
	Sub-market type	Auction market	Auction market	
Services	**Service**	Congestion Management, Voltage Control	Congestion Management, Voltage Control	
Product	**Type of product**	Active power Availability	Active Power Activation	
	OneNet Harmonised product acquired	Predictive short-term local active	Predictive short-term local active	
	Technical requirements	As defined for Predictive short-term local active	As defined for Predictive short-term local active	See section 4.2 and [9]
Location	**Level of spatial granularity**	Distribution system areas, a substation, a Feeder	Distribution system areas, a substation, a Feeder	The grain size is related to the natural structure of the distribution network. The areas are defined by DSOs according to the network needs: CM for MV / LV lines and voltage level regulation for substations. The structure is defined once, changes are made when the network is expanded and developed.
	Responsible System Operator	DSO	DSO	
	Voltage Level where resources are located	MV, LV	MV, LV	
Market Roles and actors	**Who is the buyer(s)**	DSO	DSO	
	Who is the seller(s)	SP - Service Providing unit	SP - Service Providing unit	
	Allowed technologies (Generators, Loads, Storage)	All technologies allowed	All technologies allowed	
	Aggregation method	No specific conditions	No specific conditions	
	Aggregation mix allowed	No specific conditions	No specific conditions	
	Who is the MO	DSO	DSO	
	Participation in submarket	Optional	Hybrid	

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Table 9.13: Description of the 'Sub-market coordination' pillar of the Theoretical Market Framework for the OneNet Polish demo

Feature	Sub-feature	POL: MT-D-P-E	POL: DA-D-P-E	Additional Information
Allocation principle of flexibility	**System operators order**	Priority for DSO	Priority for DSO	
	TSO access to DERs	Yes	Yes	
	Commitment to bid selection	Not Applicable	From MT-D-P-AE: Conditional	Participation forwarding based on the condition established in the availability bid
	Forwarding of bids	Not Applicable	To: DA-TD-P-AE	Aggregated bid forwarding based on network topology (for balancing).
Timeframe for coordination	**Market phase for coordination between submarkets**	With ST-D-P-A: Technical pre-qualification, Procurement	With DA-TD-P-AE: Technical pre-qualification, Procurement	

Table 9.14: Description of the 'Market optimisation' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Polish demo

Feature	POL: MT-D-P-E	POL: DA-D-P-E	Additional Information
Market optimisation	Decentralised	Decentralised	
Submarkets optimisation strategy	Sequential	Sequential	
Sub-market clearing objective	Minimisation of cost, Maximisation of social welfare	Minimisation of cost, Maximisation of social welfare	

Table 9.15: Description of the 'Market operation' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Polish demo

Feature	Sub-feature	POL: MT-D-P-E	POL: DA-D-P-E	Additional Information
Remuneration scheme		Auctions pay-as-bid.	Auctions pay-as-bid.	
Remunerated product attribute		Active Power Availability	Active Power Activation	
Market clearing type		Discrete	Discrete	
Procurement frequency		Event-based on DSO call	Event-based on DSO call	
Bid properties	**Minimum bid size**	1 kW	1 kW	
	Bid structure	Simple	Simple	

Table 9.16: Description of the 'Network representation' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Polish demo

Feature	POL: MT-D-P-E	POL: DA-D-P-E	Additional Information
Representation of network constraints	Partial grid data	Partial grid data	
Timing of the inclusion of network constraints	Definition of procurement areas Procurement phase	Definition of procurement areas Procurement phase	

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9.2.3 Theoretical market framework tables for the Czech demonstrator

Table 9.17: Description of the 'Entire market architecture' pillar using the Theoretical Market Framework for the OneNet Czech demo

Feature	Sub-feature	CZE: ALL-D-PQ-A	CZE: LT-D-Q-A	CZE: LT-D-P-A	CZE: ST-D-Q-E	CZE: ST-D-P-E	Additional Information
Submarkets	**Number of submarkets**	5					
	Gate Opening Time (GOT)	Term-period agnostic	Month(s) ahead	Month(s) ahead	Day ahead	Day ahead	
	Gate Closure Time (GCT)	Term-period agnostic	Month(s) ahead	Month(s) ahead	Day ahead	Day-ahead	
	Market Time Unit (MTU)	Hourly	Hourly	Hourly	Hourly	Hourly	
	Sub-market type	Auction market	Auction market	Auction market	Auction market	Auction market	
Services	**Service**	Congestion Management, Voltage control	Congestion Management, Voltage control	Congestion Management, Voltage control	Congestion Management, Voltage Control	Congestion Management, Voltage Control	
Product	**Type of product**	Active Power Availability	Reactive Power Availability	Active Power Availability	Reactive power Activation	Active Power Activation	
	OneNet Harmonised product acquired	Predictive long-term local reactive , Predictive long-term local active, Predictive short-term local reactive, Predictive short-term local active	Predictive long-term local reactive	Predictive long-term local active	Predictive short-term local reactive	Predictive short-term local active	
	Technical requirements	As defined for the applicable products	As defined for Predictive long-term local reactive	As defined for Predictive long-term local active	As defined for Predictive short-term local reactive	As defined for Predictive short-term local active	See section 4.2 and [9]
Location	**Level of spatial granularity**	Distribution system areas	Distribution system areas	Distribution system areas	Distribution system areas	Distribution system areas	
	Responsible System Operator	DSO	DSO	DSO	DSO	DSO	
	Voltage Level where resources are located	MV, LV	MV, LV	MV, LV	MV, LV	MV, LV	
Market Roles and actors	**Who is the buyer(s)**	DSO	DSO	DSO	DSO	DSO	
	Who is the seller(s)	Service Providing unit and group	Service Providing unit and group	Service Providing unit and group	Service Providing unit and group	Service Providing unit and group	
	Allowed technologies (Generators, Loads, Storage)	All technologies allowed	All technologies allowed	All technologies allowed	All technologies allowed	All technologies allowed	
	Aggregation method	No specific condition	No specific condition	No specific condition	No specific condition	No specific condition	
	Aggregation mix allowed	No specific condition	No specific condition	No specific condition	No specific condition	No specific condition	
	Who is the MO	IMO	IMO	IMO	IMO	IMO	
	Participation in submarket	Optional	Optional	Optional	Hybrid	Hybrid	

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Table 9.18: Description of the 'Sub-market coordination' pillar of the Theoretical Market Framework for the OneNet Czech demo

Feature	Sub-feature	CZE: ALL-D-PQ-A	CZE: LT-D-Q-A	CZE: LT-D-P-A	CZE: ST-D-Q-E	CZE: ST-D-P-E	Additional Information
Allocation principle of flexibility	**System operators order**	Exclusivity for DSO	Exclusivity for DSO	Exclusivity for DSO	Exclusivity for DSO	Exclusivity for DSO	
	TSO access to DERs	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	
	Commitment to bid selection	Not applicable	Not applicable	Not applicable	From LT-D-P-A: Formal	From LT-D-P-A: Formal	
	Forwarding of bids	Not applicable	Not applicable	Not applicable	Not Applicable	To: IDM energy	
Timeframe for coordination	**Market phase for coordination between submarkets**	Not applicable	With ST-D-Q-E: Technical pre-qualification, Procurement	With ST-D-P-E: Technical pre-qualification, Procurement	With LT-D-Q-A: Technical pre-qualification, Procurement	With LT-D-P-A: Technical pre-qualification, Procurement	

Table 9.19: Description of the 'Market optimisation' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Czech demo

Feature	CZE: ALL-D-PQ-A	CZE: LT-D-Q-A	CZE: LT-D-P-A	CZE: ST-D-Q-E	CZE: ST-D-P-E	Additional Information
Market optimisation	Decentralised	Decentralised	Decentralised	Decentralised	Decentralised	
Submarkets optimisation strategy	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	
Sub-market clearing objective	Minimisation of cost	Minimisation of cost	Minimisation of cost	Minimisation of cost	Minimisation of cost	

Table 9.20: Description of the 'Market operation' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Czech demo

Feature	Sub-feature	CZE: ALL-D-PQ-A	CZE: LT-D-Q-A	CZE: LT-D-P-A	CZE: ST-D-Q-E	CZE: ST-D-P-E	Additional Information
Remuneration scheme		Auctions pay-as-bid.			Auctions pay-as-bid.	Auctions pay-as-bid.	
Remunerated product attribute		Active and Reactive Power Availability	Reactive Power Availability	Active Power Availability	Reactive Power Activation	Active Power Activation	
Market clearing type		Discrete	Discrete	Discrete	Discrete	Discrete	
Procurement frequency		Event based	Event based	Event based	Daily	Daily	
Bid properties	**Minimum bid size**	1 kW	1 kW	1 kW	1 kW	1 kW	
	Bid structure	Simple	Simple	Simple	Simple	Simple	

Table 9.21: Description of the 'Network representation' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Czech demo

Feature	CZE: ALL-D-PQ-A	CZE: LT-D-Q-A	CZE: LT-D-P-A	CZE: ST-D-Q-E	CZE: ST-D-P-E	Additional Information
Representation of network constraints	Comprehensive grid data Partial grid data Empirical rules	Comprehensive grid data Partial grid data Empirical rules	Comprehensive grid data Partial grid data Empirical rules	Comprehensive grid data Partial grid data Empirical rules	Comprehensive grid data Partial grid data Empirical rules	
Timing of the inclusion of network constraints	Definition of procurement areas Procurement phase	Definition of procurement areas Procurement phase	Definition of procurement areas Procurement phase	Definition of procurement areas Procurement phase	Definition of procurement areas Procurement phase	

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9.2.4 Theoretical market framework tables for the Hungarian demonstrator

Table 9.22: Description of the 'Entire market architecture' pillar using the Theoretical Market Framework for the OneNet Hungarian demo

Feature	Sub-feature	HUN: WA-D-PQ-A-E	HUN: DA-D-PQ-E	Additional Information
Submarkets	**Number of submarkets**	2		
	Gate Opening Time (GOT)	Month(s) ahead	Day-ahead	
	Gate Closure Time (GCT)	Week-ahead, W-1 workday afternoon	Day-ahead	
	Market Time Unit (MTU)	Hourly	Hourly	
	Sub-market type	Auction market	Auction market	
Services	**Service**	Congestion Management, Voltage Control	Congestion Management, Voltage Control	
Product	**Type of product**	Active power Availability Active power Activation Reactive Power Availability Reactive Power Activation	Active power Activation Reactive Power Activation	
	OneNet Harmonised product acquired	Predictive short-term local active Predictive short-term local reactive	Predictive short-term local active Predictive short-term local reactive	
	Technical requirements	As defined for Predictive short-term local active and Predictive short-term local reactive	As defined for Predictive short-term local active and Predictive short-term local reactive	See section 4.2 and [9]
Location	**Level of spatial granularity**	Distribution system areas	Distribution system areas	
	Responsible System Operator	DSO	DSO	
	Voltage Level where resources are located	MV	MV	
Market Roles and actors	**Who is the buyer(s)**	DSO	DSO	
	Who is the seller(s)	Service Providing unit and group	Service Providing unit and group	
	Allowed technologies (Generators, Loads, Storage)	All technologies allowed	All technologies allowed	
	Aggregation method	Aggregation at the same level as the locational granularity of the market	Aggregation at the same level as the locational granularity of the market	
	Aggregation mix allowed	All technologies allowed	All technologies allowed	
	Who is the MO	DSO	DSO	
	Participation in submarket	Optional	Optional	

Table 9.23: Description of the 'Sub-market coordination' pillar of the Theoretical Market Framework for the OneNet Hungarian demo

Feature	Sub-feature	HUN: WA-D-PQ-A-E	HUN: DA-D-PQ-E	Additional Information
Allocation principle of flexibility	**System operators order**	Exclusivity for DSO	Exclusivity for DSO	
	TSO access to DERs	Not Applicable	Not Applicable	
	Commitment to bid selection	Not Applicable	Not Applicable	
	Forwarding of bids	Not Applicable	Not Applicable	Bid forwarding from ST-D-P-E to intraday energy auction has been conceptually investigated
Timeframe for coordination	**Market phase for coordination between submarkets**	With DA-D-PQ-E: Procurement	With WA-D-PQ-E: Procurement	

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Table 9.24: Description of the 'Market optimisation' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Hungarian demo

Feature	HUN: WA-D-PQ-A-E	HUN: DA-D-PQ-E	Additional Information
Market optimisation	Decentralised	Decentralised	
Submarkets optimisation strategy	Sequential	Sequential	
Sub-market clearing objective	Minimisation of cost	Minimisation of cost	

Table 9.25: Description of the 'Market operation' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Hungarian demo

Feature	Sub-feature	HUN: WA-D-PQ-A-E	HUN: DA-D-PQ-E	Additional Information
Remuneration scheme		Auctions pay-as-bid.	Auctions pay-as-bid.	
Remunerated product attribute		Active and reactive power activation	Active and reactive power activation	
Market clearing type		Discrete	Discrete	
Procurement frequency		Weekly	Daily	
Bid properties	**Minimum bid size**	50 kW	50 kW	
	Bid structure	Simple	Simple	

Table 9.26: Description of the 'Network representation' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Hungarian demo

Feature	HUN: WA-D-PQ-A-E	HUN: DA-D-PQ-E	Additional Information
Representation of network constraints	Comprehensive grid data , Partial grid data	Comprehensive grid data , Partial grid data	
Timing of the inclusion of network constraints	Definition of procurement areas Procurement phase	Definition of procurement areas Procurement phase	

9.2.5 Theoretical market framework tables for the Northern cluster demonstrator

Table 9.27: Description of the 'Entire market architecture' pillar using the Theoretical Market Framework for the OneNet Northern Cluster demos

Feature	Sub-feature	NOC: LT-TD-P-(A-E)	NOC: ST-TD-P-A	NOC: ST-TD-P-E	NOC: NRT-TD-P-E	Additional Information
Submarkets	**Number of submarkets**	4				
	Gate Opening Time (GOT)	More than month ahead (even years)	Mont-ahead to day-ahead	Day-ahead	Near-real-time	
	Gate Closure Time (GCT)	Month ahead	Day-ahead	Intraday (2 hours ahead of Time of Service Delivery)	Near-real-time	
	Market Time Unit (MTU)	1 hour	1 hour	1 hour	1 hour	
	Sub-market type	Auction market	Auction market	Auction market	Auction market	
Services	**Service**	Agnostic (Frequency control, congestion management, adequacy)	Agnostic (Freq. control, congestion management)	Congestion Management	Agnostic (Freq. control, congestion management)	
Product	**Type of product**	Active power Availability and Active power Activation	Active power Availability	Active power Activation	Active power Activation	
	OneNet Harmonised product acquired	LT-P-C/E	ST-P-C	ST-P-E	NRT-P-E (includes mFRR energy)	

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	Technical requirements	As defined for LT-P-C/E	As defined for ST-P-C	As defined for ST-P-E	As defined for NRT-P-E	See section 4.2 and [9]
Location	**Level of spatial granularity**	National, Zones transmission, Distribution system.	National, Zones transmission, Distribution system.	National, Zones transmission, Distribution system.	National, Zones transmission, Distribution system.	Bids with locational information
	Responsible System Operator	TSO, DSO	TSO, DSO	TSO, DSO	TSO, DSO	
	Voltage Level where resources are located	HV, MV, LV	HV, MV, LV	HV, MV, LV	HV, MV, LV	
Market Roles and actors	**Who is the buyer(s)**	TSO, DSO	TSO, DSO	TSO, DSO	TSO, DSO	
	Who is the seller(s)	Service Providing unit and group	Service Providing unit and group	Service Providing unit and group	Service Providing unit and group	
	Allowed technologies (Generators, Loads, Storage)	All technologies allowed	All technologies allowed	All technologies allowed	All technologies allowed	
	Aggregation method	At same locational granularity as the market	At same locational granularity as the market	At same locational granularity as the market	At same locational granularity as the market	
	Aggregation mix allowed	All technologies	All technologies	All technologies	All technologies	
	Who is the MO	DSO, TSO, IMO	DSO, TSO, IMO	DSO, TSO, IMO	DSO, TSO, IMO	
	Participation in submarket	Optional	Optional	Hybrid	Hybrid	mandatory in case SP has been remunerated for availability

Table 9.28: Description of the 'Sub-market coordination' pillar of the Theoretical Market Framework for the OneNet Northern Cluster demos

Feature	Sub-feature	NOC: LT-TD-P-(A-E)	NOC: ST-TD-P-A	NOC: ST-TD-P-E	NOC: NRT-TD-P-E	Additional Information
Allocation principle of flexibility	**System operators order**	No Priority	No Priority	No Priority	No Priority	
	TSO access to DERs	Yes	Yes	Yes	Yes	
	Commitment to bid selection	Not Applicable	Not Applicable	From LT-TD-P-(A-E): Formal From Intraday energy market: Formal	From ST-TD-P-E: Formal	
	Forwarding of bids	No	No	To Intraday energy market To NRT-TD-P-E	No	
Timeframe for coordination	**Market phase for coordination between submarkets**	Not applicable	Not applicable	With Intraday Energy Market: Technical pre-qualification, Procurement	Not Applicable	

Table 9.29: Description of the 'Market optimisation' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Northern Cluster demos

Feature	NOC: LT-TD-P-(A-E)	NOC: ST-TD-P-A	NOC: ST-TD-P-E	NOC: NRT-TD-P-E	Additional Information
Market optimisation	Centralised	Centralised	Centralised	Centralised	
Submarkets optimisation strategy	Sequential	Sequential	Sequential (simultaneous with Intraday energy market)	Sequential	
Sub-market clearing objective	Minimisation of cost	Minimisation of cost	Minimisation of cost	Minimisation of cost	

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Table 9.30: Description of the 'Market operation' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Northern Cluster demos

Feature	Sub-feature	NOC: LT-TD-P-(A-E)	NOC: ST-TD-P-A	NOC: ST-TD-P-E	NOC: NRT-TD-P-E	Additional Information
Remuneration scheme		Uniform pay-as-cleared	Uniform pay-as-cleared for ST-P-C	Pay-as-bid for ST-P-E	Pay-as-bid in the demo phase. Uniform pay-as-cleared to be discussed further.	
Remunerated product attribute		Active Power Availability Active Power Activation	Active power availability The capacity part of the existing mFRR, which is used as an available reserve capacity for frequency restoration, can be an example of this product. I	Active Power Activation	Active power Activation	
Market clearing type		Discrete	Discrete	Discrete	Discrete	
Procurement frequency		More than monthly	Daily on event-based on DSO call	Intraday	Intraday	SO-MO coordination for the request to open the market happens trough the T&D coordination platform
Bid properties	**Minimum bid size**	0.1 MW	0.1 MW	0.1 MW	0.1 MW	
	Bid structure	Non-symmetric and non-divisible products permitted	Non-symmetric and non-divisible products permitted	Non-symmetric and non-divisible products permitted	Non-symmetric and non-divisible products permitted	

Table 9.31: Description of the 'Network representation' pillar of the Theoretical Market Framework of the Short-Term markets designed for the OneNet Northern Cluster demos

Feature	NOC: LT-TD-P-(A-E)	NOC: ST-TD-P-A	NOC: ST-TD-P-E	NOC: NRT-TD-P-E	Additional Information
Representation of network constraints	Comprehensive grid data, Partial grid data	Comprehensive grid data, Partial grid data	Comprehensive grid data, Partial grid data	Comprehensive grid data, Partial grid data	
Timing of the inclusion of network constraints	Procurement phase	Procurement phase	Procurement phase	Procurement phase	

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9.3 Survey on the demo design drivers for large scale harmonised prequalification procedures adoption

In this section, the results of the survey on the demo design drivers for large scale harmonised prequalification procedures adoption are reported. The following 3-points scale has been used for rating:

H	Highly relevant
S	Somewhat relevant
N	Not relevant

9.3.1 Common prequalification procedure across SOs

Benefits	NOC	CZE	POL	GRC	PRT	ESP
Reduced Administrative Burden: A shared procedure would reduce the administrative and operational burden on service providers who work with both DSOs and TSOs.	H	H	H	H	N	S
Reduced Barriers for Market Participants: One common procedure would simplify entry into the market, encouraging more participants and fostering competition.	H	H	S	S	N	S
Enhanced Coordination: It would foster better coordination between transmission and distribution levels.	H	S	H	H	H	S
Optimised Utilisation: With shared prequalification, a flexibility resource could be used more efficiently across both levels of the grid, ensuring optimal system operation.	H	H	S	H	H	S
Reduced costs for service provision: Avoiding duplicated procedures for SPs reduces the corresponding operating costs that reflects to the lower costs for service provision.	H	S	N	S	N	S
Threats						
Complexity: Reaching consensus on standards that cater to the unique needs of both DSOs and TSOs could be challenging. A unified standard might not provide the flexibility needed for unique regional or operational challenges faced by individual DSOs or TSOs.	S	N	S	S	H	H
Implementation Challenges: Transitioning to a shared procedure could entail significant operational and administrative changes, possibly causing disruptions.	N	S	S	N	S	H
Potential for Conflicts: DSOs and TSOs have different operational objectives and responsibilities, which could lead to conflicts in determining shared standards and in operating the jointly qualified resources.	S	N	S	S	H	H
REQUIREMENTS (MUST HAVE CONDITIONS)						
Interoperable platforms for prequalification: To ensure seamless and timely information exchange across the System Operators' control centres, there is the need for interoperable platforms and data exchange protocols.	S	S	H	H	H	H
Robust Communication Infrastructure for prequalification: Ensuring seamless communication between DSOs and TSOs. Infrastructures to allow the necessary high-speed communication across the actors involved with the necessary level of redundancy and reliability.	N	H	S	H	H	H

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Shared Data Repositories: Platforms where relevant data is collated, standardised, and made accessible to relevant entities, ensuring transparency and promoting trust.	H	S	H	H	S	S
Stakeholder Engagement: Involvement of all relevant stakeholders, including DSOs, TSOs, regulators, and service providers, in the decision-making process.	H	H	S	N	S	N
Detailed Requirement Analysis: A thorough analysis of the current and future (technical) requirements of both DSOs and TSOs to create an effective shared procedure.	S	H	H	S	S	N
Uniform Prequalification Criteria: While the specific operational requirements of DSOs and TSOs may differ, the outcome of the prequalification procedure must adhere to a common set of criteria ensuring interoperability.	H	H	H	S	S	S
ENABLERS (NICE TO HAVE CONDITIONS)						
Regulatory Support: Clear mandates and guidelines from regulatory authorities can act as a significant enabler. A framework that allows for adaptability as technology and market dynamics evolve, but still ensures system security and reliability.	H	H	H	H	H	H
Incentive Mechanisms: Regulatory incentives that promote DSO and TSO collaboration, rewarding innovations and efficiency in shared procedures.	H	S	N	N	S	N
Stakeholder Forums: Regular forums or platforms where DSOs, TSOs, regulators, technology providers, and other stakeholders can collaborate, share insights, and jointly evolve the shared prequalification processes. Establishing mechanisms for participants to provide feedback, which can be used to refine and perfect the shared procedures.	S	S	S	S	S	S
Benchmarking: Regularly revisiting and benchmarking the outcomes against international best practices and evolving grid requirements.	N	H	S	S	N	S
Pilot Projects and Test Beds: Initial pilot projects can help understand the challenges and benefits before full-scale implementation.	H	H	H	H	S	H
Digital Twins: Creating virtual replicas of the physical grid system to run simulations, test and optimise shared prequalification procedures without affecting the real system.	S	S	S	N	H	H
Quality Assurance: Implementing robust quality control and assurance mechanisms to ensure that the outcomes consistently meet the shared standard requirements.	S	H	H	N	H	H
Joint Training Initiatives: Unified training programs ensuring that personnel across DSOs and TSOs are aligned in understanding and executing the shared procedures.	S	S	S	N	H	S
BARRIERS						
Differing Objectives: DSOs and TSOs have different operational goals which can act as a barrier.	S	S	N	H	S	H
Operational Inertia (or Path Dependency): Established operational protocols might resist change.		N	S	S	N	S
Data Privacy Concerns: Sharing information between entities might raise data privacy and security concerns.	S	S	N	H	H	S

9.3.2 Common prequalification procedure across multiple products

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Benefits	NOC	CZE	POL	GRC	PRT	ESP
Reduced Administrative Burden: Sharing a single prequalification procedure for multiple products can simplify the administrative process, reducing costs and effort for both system operators and potential providers.	H	H	S	H	H	S
Value Stacking for Providers: Providers might find it easier to pivot between different system services, based on market needs and price signals, if they have already been prequalified for a range of products.	H	H	H	S	S	S
Faster Time to Market: With fewer procedures to navigate, providers might be able to offer their services to the market more rapidly.	S	H	H	N	N	N
Increased Participation: By simplifying and streamlining the prequalification procedure, more providers may be incentivised to participate, fostering competition and potentially reducing costs for system services.	S	S	N	N	N	S
Threats						
Potential for Lowered Standards: One size does not always fit all. A shared procedure might not adequately address the unique requirements of each product, leading to reliability issues.	N	N	H	H	H	H
Risk of Stifling Innovation: Unique prequalification procedures for different products allow for innovative solutions tailored to specific service needs. A unified procedure might inadvertently hinder these specialised innovations.	N	S	H	N	N	N
Barriers to Specialisation: Some providers specialise in specific system services. By combining prequalification, these specialists might face challenges if the combined criteria don't align with their particular strengths.	N	N	H	S	N	H
Complexity: Merging various criteria for different products into a unified prequalification process can result in a more complex and confusing procedure rather than simplifying it.	N	S	H	H	H	H
REQUIREMENTS (MUST HAVE CONDITIONS)						
Standardised (Unified) Technical Requirements: Universal technical specifications (i.e., standardised or harmonised product specifications) for products across different system services can make shared prequalification more feasible. Consensus on the technical requirements that ensure the stability, safety, and efficient grid operation.	H	H	H	H	S	H
Interoperable IT Systems: Systems that are compatible across different services can seamlessly share and process data, making shared prequalification more efficient.	H	S	H	H	H	N
Requirements Adequacy: While the procedure may be common, there should be flexibility within the criteria to cater to the specific nuances and requirements of each product. Different products may have different risk profiles. The common prequalification procedure should incorporate risk assessment and management tools.	H	N	S	N	S	H
Pilot Testing: Before fully implementing a common prequalification procedure, pilot testing could be conducted to assess its viability and adjust it based on real-world feedback.	H	H	H	H	H	H

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Unified Regulatory Framework: Unified regulatory framework and guidelines for all system services can smoothen the transition towards shared prequalification (i.e. Table of Equivalence).	H	H	H	N	H	H
Neutrality: The prequalification process should be designed with a clear understanding of the market dynamics, ensuring that it does not unintentionally stifle competition or favour a particular set of providers.	H	H	H	N	S	H
ENABLERS (NICE TO HAVE CONDITIONS)						
Clear Economic Incentives: Clear economic benefits, such as cost savings, increased efficiency, or better resource allocation, make shared prequalification more attractive. If all the stakeholders, including service providers, regulators, and consumers, see the benefits are onboard with shared prequalification, it can be smoothly implemented.	H	H	S	N	S	H
Transparent and Uniform Procedures: Procedures that are transparent and uniform across services can simplify the prequalification process and make it more accessible. A common procedure should ideally simplify the documentation process, making it easier for providers to understand and comply with the requirements.	H	S	S	H	H	H
Flexible Integration Mechanisms: The ability to integrate new products or services without overhauling the entire system is crucial.	H	H	S	H	N	S
Robust Dispute Resolution Mechanism: Given the potential for disagreements or disputes, a clear, fair, and swift resolution mechanism should be in place.	S	H	S	N	N	H
Continuous Training and Capacity Building: For the common procedure to be effective, continuous training programs should be conducted for all stakeholders, ensuring they're updated about the latest requirements, technologies, and standards.	S	N	S	N	H	H
Feedback Mechanism: An effective feedback system should be in place, allowing service providers to voice their concerns, suggestions, or challenges regarding the common prequalification procedure.	H	N	N	N	N	H
BARRIERS						
Divergent Technical Needs: If the technical requirements for different system services and different products are too varied, shared prequalification might introduce inefficiencies.	N	N	N	S	S	H
Incompatible IT Systems: Different services might have legacy IT systems that are incompatible, making data sharing and processing difficult.	N	S	N	N	S	S
Potential for Service Disruption: If there's a risk that shared prequalification might disrupt the provision or quality of system services, it can be a major deterrent.	N	H	N	N	H	H
Conflicting Regulatory Mandates: If regulation for different system services have conflicting requirements or standards, shared prequalification becomes challenging.	S	H	S	N	H	H
Ambiguous Economic Outcomes: If the economic benefits of shared prequalification are unclear or unevenly distributed, there might be resistance to its adoption.	S	S	N	N	S	H

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Lack of Stakeholder Consensus: Resistance from any key stakeholder can halt the progress towards shared prequalification.	S	S	H	N	S	S
Complex Integration Procedures: If integrating the prequalification processes of different services becomes too complex, it might be more efficient to keep them separate.	S	H	H	S	H	H

9.3.3 Common prequalification procedure for single units and groups

	Demo rating					
Argument Description	NOC	CZE	POL	GRC	PRT	ESP
Benefits						
Economies of Scale: Aggregating multiple assets can lead to cost savings in prequalification, operation, and management.	H	S	H		S	S
Versatility: A portfolio can provide a more versatile response to service requests or market conditions, leveraging the combined capabilities of different assets.	H	S	H		H	S
Optimised Asset Utilisation: By understanding the synergies and capabilities of assets collectively, there's potential for better overall asset utilisation and performance	H	H	S		S	H
Market Accessibility for Smaller Units: Establishing prequalification at the portfolio level allows for the aggregation of smaller units or assets that individually might not meet the minimum size or capacity requirements for standalone prequalification.	H	H	H		H	H
Risk Diversification: Risks associated with individual assets can be offset by the performance of others, creating a more resilient and stable portfolio.	H	H	S		H	S
Threats						
Increased Complexity: Managing and prequalifying multiple assets collectively can be more complex than handling individual assets.	N	S	H		S	N
Standardisation Challenges: Different assets might have different standards or come from different vendors, leading to integration and standardisation issues.	S	H	H		H	S
Operational Challenges: Maintaining consistent performance across a diverse portfolio can be challenging, especially if individual assets have distinct operational requirements.	N	H	H		S	S
Stakeholder Resistance: Existing stakeholders might resist the shift from individual asset prequalification due to concerns about transparency, accountability, or privacy concerns.	N	S	S		N	S
Higher Initial Costs: There could be higher upfront costs in integrating diverse assets, setting up unified monitoring and control systems, and potential standardisation issues.	N	H	N		S	S
No SO need for a distributed portfolio of units: for some services, SOs may specifically require service provision from units	N	N	H		S	N
REQUIREMENTS (MUST HAVE CONDITIONS)						
Portfolio Management Framework: A comprehensive framework that can capture the synergies and complexities of diverse assets in a portfolio.	S	S	S		H	H

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Aggregate Performance Metrics: Metrics that can evaluate the collective performance and capabilities of the entire portfolio.	H	H	S		S	S
Advanced Monitoring & Control Systems: Systems capable of gathering real-time data and controlling multiple assets in the portfolio.	N	H	H		H	H
Interoperability Standards: Standards to ensure different assets, possibly from different vendors or manufacturers, can communicate and function harmoniously.	N	S	S		H	S
Detailed Asset Documentation: Information on each asset's capabilities, constraints, history, and operational characteristics.	S	S	S		H	H
ENABLERS (NICE TO HAVE CONDITIONS)						
Scalability: The prequalification process should accommodate the potential addition or removal of assets from the portfolio.	H	N	S		S	N
Regulatory Support: Regulations that encourage or allow for portfolio-level prequalification.	H	N	S		H	H
Advanced IT Systems: Modern IT platforms that can process large datasets, employ analytics, and provide insights on the entire portfolio.	H	H	H		H	H
Integrated Data Repositories: Unified databases that collect, store, and analyse data from every asset in the portfolio.	H	H	S		S	S
Knowledge & Expertise: Human expertise to understand the intricacies and potential synergies of managing multiple assets as one entity.	H	H	S		S	H
Industry Collaboration: Collaboration between various stakeholders to develop standards, share best practices, and provide feedback.	S	S	S		S	H
BARRIERS						
Lack of Standards: Absence of industry-wide standards for portfolio-level assessments.	S	N	N		S	H
Integration Challenges: If assets have been procured from different vendors or are based on different technological platforms, integrating them into one portfolio might be technically challenging.	H	H	N		H	S
Regulatory Hurdles: Current regulations might not be geared towards portfolio-level prequalification, necessitating changes or adaptations in regulatory frameworks.	N	S	S		N	H
Complexity: The inherent complexity in assessing multiple assets collectively, especially if they are diverse in nature.	S	H	S		S	S
Economic Hurdles: It might be financially challenging to integrate various assets or establish new systems for portfolio-level management.	S	H	S		S	S
Resistance to Change: Established organisations might be resistant to moving away from individual asset prequalification due to the costs or perceived risks.	N	S	N		N	S
Data Privacy and Security Concerns: As more assets are interconnected, concerns about data breaches or unauthorised access might arise.	H	S	S		H	H

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