EU wide implementation challenges of **market design**

PUBLIC CONSULTATION OneNet Roadmap (PART 1)

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

1 Introduction

The OneNet project [2020 – 2024 - Homepage - OneNet Project (onenet-project.eu)] has analyzed in depth the existing barriers to move towards a more consumer-oriented, coordinated and integrated European Market Design. A set of solutions has been developed in the project, supported by insights from 15 large demonstrators that verified feasibility and effectiveness of the proposed solutions.

This consultation document provides a summary of main policy recommendations for market design. The document is structured along eight thematic areas, each accompanied by a brief key message outlining the proposed steps forward. Through a thorough analysis, we have identified key enablers and barriers tied to each set of solutions, taking into account regulatory, economic, and technical considerations. Furthermore, we identified the timing (short-term, medium-term, long-term) and appropriate level of intervention (local, national, European) for each barrier and enabler.

As we move towards the end of the project, we would like to engage with a diverse array of stakeholders to validate our assessment. We would like to have your feedback on following questions (*):

1) *From the selection of 8 thematic areas, what are the top three solutions or thematic areas that you believe should be prioritized on policy agendas?*
2) *In your view, what are the main barriers and enablers for these solutions or thematic areas?*
3) *What concrete recommendations do you propose for further policy development in these areas?*
4) *Are there any gaps or topics currently not addressed that you deem important for achieving an integrated, coordinated market?*

(*) any additional comments or feedback are of course also welcome

➔ Answers could be provided to: Helena Gerard (helena.gerard@vito.be), Jacob Mason (Jacob.mason@vito.be) **until 12/03/2024**

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2 Market Design

The solutions developed within OneNet that relate to market design each support one or more key messages. These key messages summarize how the solutions and recommendations enable a coordinated and integrated market, as well as how they surmount the many barriers defined in [1]. A total of 8 key messages are presented below, along with enablers and barriers and recommendations that have been observed throughout the project. The enablers and barriers are economic, regulatory, or technical topics that currently inhibit or promote the implementation of the key messages. An additional layer is added that defines what level of geographic intervention at which each of these enablers and barriers should be addressed: local, national, or EU-wide.

8 Thematic areas
Market Participation and Consumer Engagement
Products & Services
Roles & Responsibilities
TSO-DSO Coordinated Flexibility Markets
Prequalification
Procurement
Settlement & Baselining
System Operator Needs

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2.1 Market Participation & Consumer Engagement

KEY MESSAGE:

Realizing the potential of flexibility markets to meet the TSOs' and DSOs' needs efficiently and reliably requires a wide participation of flexibility resources. With the growing need for flexibility at the different voltage levels of the grid and the increased ability of end-consumers to control their consumption, generation, and storage schedules, flexibility from the demand-side (in particular, from small-scale consumers) will play an indispensable role. Consumers' participation in flexibility markets enables them to improve the valorisation potential of their flexibility assets (and hence drives incentives for investments therein), and supports the safe and efficient operation of the grid. Wide-scale consumer participation is needed to: (i) support liquidity in flexibility markets, and hence, help realize their maximized efficiency potential, and (ii) ensure that an adequate volume of flexibility is available to ensure the reliable operation of the grids (at the transmission and distribution levels).

OneNet recognizes the need for increased market participation through improved consumer-engagement in electricity and flexibility markets and the development of consumer-centric electricity and flexibility market designs. This is achieved through three dimensions:

- Consumer-engagement strategies in flexibility markets: consumer-engagement strategies, identified economic, behavioural, legal and technical barriers, and solutions therefore
- Consumer-supportive business models:
- Consumer-centric flexibility markets: defining what consumer-centricity implies regarding the design of TSO-DSO coordination flexibility markets, thus standardizing the backdrop upon which future solutions can be developed.

Solutions:

Solution	OneNet Deliverable(s)
Guidelines for tackling barriers hindering market participation	D3.3, D11.5, D11.6
Consumer-centric TSO-DSO coordinated markets	D3.3, D11.5, D11.6

Guidelines for Tackling Barriers Hindering Market Participation

Given the growing availability of flexible resources on the side of end-users, there's an indispensable need to increase their participation in flexibility markets to unlock their flexibility for providing the needed services for the grid. OneNet delves into customer engagement strategies and the current barriers therefor, while providing recommendations to overcome such barriers and improve the participation potential for end-users.

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The analysis covered economic, behavioral, legal, and technical barriers including risk & uncertainty, status-quo bias, and data exchange, among others. Through development of these guidelines, OneNet proposes recommendations for regulators, governments, TSOs, DSOs, service providers, and other key stakeholders that enable them to address each barrier. In addition, OneNet has focused on business models in flexibility markets considering the different stakeholders, while considering the impact on the consumer participation potential in flexibility markets. These aspects are further detailed next.

- Defining engagement strategies for consumer participation in flexibility markets along with the economic, behavioral, legal, and technical barriers thereof. In addition, recommendations to address those barriers were defined.
    - To address **economic** barriers, OneNet focused on increasing the value of flexibility, reducing economic risk and uncertainty, and developing a suitable market and product design. The recommendations focus on improving value stacking, increasing digitization via interoperable devices, ensuring economically vulnerable groups are included, standardizing registration process, and investing in research into advanced customer profiles to assess costs and benefits of solutions more accurately.
    - The OneNet guidelines for **behavioral** components aim to improve knowledge of customers, promote flexibility markets awareness campaigns, and utilize effective and clear communication for flexibility-related offers.
    - **Legal** barriers are addressed by improving regulatory frameworks for more inclusive flexibility markets, establishing fair and robust energy contracts that enable switching, promoting best practices, minimizing ambiguities in standards, and promoting digitalization.
    - Regarding the **technical** barriers, OneNet explored the barriers that can be induced by different flexibility products attributes, and analyzed the way such barriers can differently materialize in different TSO-DSO coordinated flexibility market models. Recommendations on market design were then provided to reduce such barriers, including key solutions such as: (i) supporting aggregation mechanisms to enable the participation of small-scale resources without requiring strict modifications to the products characteristics (thus enabling consumer participation while not jeopardizing the reliable delivery of services), and (ii) the addition of local market layers (in addition to centralized common market layers) to enable small-scale resources to contribute their flexibility for local grid needs, which would have otherwise not been able to participate when considering centralized market models, as those would likely adopt more stringent product and services requirements which may be difficult to meet by small-scale resources without aggregation.

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- In addition, OneNet proposes tackling **technical** barriers through the anticipation of user's needs regarding infrastructure and product design, unifying data models and protocols, providing user-friendly interfaces, and supporting third-party technical enablers and support structures.

- Defining business models for engaging consumers in flexibility markets and overcoming existing regulatory barriers (D11.6). Several stakeholder perspectives were addressed across the OneNet demos to understand how different technical and regulatory environments impact their engagement into the local markets. For example, business models for aggregators/FSPs were analysed as they provide a direct link to consumers to engage their participation and provide them with fair remuneration for their flexibility.

Consumer-Centric TSO-DSO Coordinated Markets

Consumer-centricity is quite often described as a requirement for electricity and flexibility markets. However, a clear definition of what consumer-centricity entails is missing. Starting from a definition of "consumer" based on EU documentation, OneNet aimed to define what makes a market consumer centric. This was then further refined to define what consumer-centricity means in the context of electricity markets and what it entails in the context of flexibility markets. This mechanism was then applied to different TSO-DSO coordinated market models to investigate their level of consumer-centricity and how they rank regarding this metric.

Indeed, the general definition of consumer-centricity requires a level of control or customizability of consumers over the products they are trading and their attributes. However, in electricity markets, that can be naturally challenging as the product attributes are rather defined, to a large extent, by the service requirements. These challenges can be alleviated through aggregators, who by offering contracts that are cognizant of the preferences and needs of consumers, would engage consumers, and enable their participation in the markets, while meeting the service requirement needs specified by the product attributes. As a result, this puts a responsibility on the aggregators for improving the participation potential of consumers in electricity and flexibility market and applying the definitions of consumer centricity to the relation between aggregators and consumers and the design of contracts for accessing their flexibility.

When focusing on the level of consumer-centricity of the different TSO-DSO coordinated market models explored in OneNet, their consumer-centricity is contingent upon their ability to first allow increased participation opportunities for consumers, thus generating value to them while ensuring a reliable delivery of

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the required services to the SO(s). The analysis on the different TSO-DSO coordination schemes in OneNet highlighted the following conclusions:

- The disjoint central market can exhibit the lowest level of consumer centricity, given that it excludes the participation of distribution-level resources.
- Disjoint distribution-level and fragmented markets allow the participation of distribution-level resources, but strictly for use by the DSOs. Thus, this provides an improved consumer-centricity level as compared to disjoint central markets, while also allowing tailoring the participation requirements to the technical needs of local flexibility resources. However, due to the limited scope of participation of end-consumers, its level of consumer-centricity can be further improved.
- The common market encourages distribution-level resources to deliver their flexibility to all the SOs as part of a joint market. This results in an increased level of consumer-centricity as it enables consumers to deliver their flexibility at a wide scale, improving their valorization potential. However, as the common market is based on a joint procurement by all SOs, the central system flexibility requirements, when harmonized for the complete market, can be stringent for local resources, thus leading to a reduction of consumer-centricity. If this aspect can be alleviated through aggregation, this would improve the consumer-centricity level of the common market.
- The multi-level market provides a high level of consumer-centricity. Similarly to the common market, it enables distribution-level resources to offer their flexibility to DSOs and TSOs. Moreover, given the multilevel market structure, which is composed of a local DSO-level market layer followed by a TSO-level market – it allows the first market layer to consider the needs of local flexibility resources more closely than in the joint common market. Thus, small-scale resources which otherwise may not have been able to participate in the common market, can potentially participate in the local layer of the multilevel market. This has a positive impact on the consumer-centricity level of the multilevel market. However, the fragmentation of the market can lead to a lower overall efficiency than the common market, leading to additional costs to be borne by consumers as part of their electricity bills, which would negatively impact the consumer-centricity level of the multilevel market.

Enablers & Barriers:

Table 1. Table of Enablers and Barriers for the above Macro Solution. Topics are grouped into Economic (E), Regulatory (R), and Technical (T) topics.

	Enablers			Barriers	
	Topic	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*		**Topic**	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*
E	**Harmonization:** Harmonized products can simplify value stacking by aligning attributes of flexibility products making it easier to combine multiple	L C E S **M** L	E	**Compensation mechanism**: Unclear and inconsistent compensation mechanisms for flexibility provided by FSPs leads to uncertainty surrounding revenue streams and economic	L C E **S** M L

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	smaller bids or bid on multiple markets, improving the business value for aggregating and thus yielding more participation opportunities for small-scale consumers.			incentives for flexibility activation and penalties for non-delivery, thus acting as a barrier for general FSPs and for aggregators and thus decreasing the participation potential of small-scale consumers.	
R	**Consumer-engagement strategies** and **consumer-centric market designs**, enabling the participation of small-scale consumers – through aggregation – in the provision of flexibility, improves the revenue streams of consumers on their flexibility assets investments, thus enabling further investments and further flexibility provision.	**L S** C M E L	R	**Transfer of Energy (ToE)**: Related to compensation mechanisms between independent aggregators and suppliers (e.g., for foregone retail revenues by the supplier due to activated flexibility by the aggregator), current regulations in most EU countries regarding ToE are unclear or non-existent. Regulations in the countries that do address ToE are inconsistent with each other as no optimal method has been established. This creates confusion surrounding roles and compensation methods for SOs, BRPs, suppliers, and FSPs which further inhibits aggregation of end-consumer flexibility.	L S **C M** E L
R		L S C M E L	R	**Aggregation**: The lack of consistent aggregation regulations prevents small-scale FSPs from participating in markets, limiting flexibility and inhibiting the development of consumer-centric markets across the EU	L **S** C M **E** L
R		L S C M E L	E R T	**Consumer Awareness:** Current market landscape lacks sufficient mechanisms to engage end-consumers (introductory market trainings, knowledge of benefits, etc.) that inhibits customer engagement and market access. The underrepresentation leads to a lack of services offered to end-consumers	L **S** **C** M E L
R		L S C M E L	R	**Product Harmonization for FSPs & Industrial Partners**: Overly strict regulation surrounding product harmonization restricts market access to new industrial players by restricting the possibilities for product innovation	L S C **M** **E** L
T	**Flexibility Tools**: The current development and widespread adoption of tools that allow users to easily evaluate, observe, and assess the value (both quantity and location) of flexibility, such as smart meters and energy management systems, are increasing the visibility of, and demand for, flexibility services	**L** S **C** **M** **E** L	T	**Technical Complexity**: The fast-changing environment for technical solutions generates highly complex and often convoluted systems for operators and consumers to navigate without extensive knowledge or study	**L** **S** **C** M **E** L
T	**Unified Market Platform**: A single platform, or a uniform platform design, for market participations to place bids, view information, and communicate together can facilitate market access by	L S **C** **M** **E** L	T	**Information Access**: Visibility regarding options for providing flexibility, system needs, and possible remuneration mechanisms are essential for driving market access and participation potential of consumers. A lack thereof results in a lack of clarity regarding the potential valorisation value, on how to deliver flexibility, and	L S **C** **M** E L

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	lowering the knowledge barrier to entry by new participants and providing a single market for all flexibility services. This contributes to improved participation potential of new aggregators and thus that of small-scale end consumers, in addition to large-scale actors (generation and consumers).			the overall transparency of the process, which negatively impacts market participation.	

Recommendations:

Facilitating market participation and developing a consumer-centric market go hand in hand for establishing coordinated and integrated markets. The shift to a focus on consumers addresses issues such as efficient market access at all voltage levels and technologies, cost-efficient flexibility activation, and a level playing field for all market actors. These are the same barriers that are currently inhibiting market participation by consumers. Therefore, by overcoming these barriers to create a more consumer-focused market, an increase in market participation can be expected in parallel.

OneNet begins the processing of achieving these goals in Europe by presenting a set of guidelines to directly address the barriers identified that hinder market participation and by developing a clear definition of what a consumer-centric TSO-DSO coordinated market looks like. The former utilized the full spectrum of market operators within the OneNet consortium to identify economic, behavioral, legal, and technical barriers associated with market participation. Bringing such clarity to the problems being addressed allowed for the development of a list of recommendations that directly address each of the barriers. These guidelines are directed towards relevant recipients. These recipients are the entities best poised to tackle the barrier and execute the recommendation: governments, regulators, municipalities, educational institutes, system and market operators, FSPs, and research institutes.

The latter solution addresses the complexities of consumer-centricity by first defining “consumer-centric” before addressing how electricity and flexibility markets could be consumer-centric within the bounds of this definition.

Both of these solutions provide an integral foundation for the further development of consumer-centric markets. However, further research and application of the solutions is imperative to address the limitations, develop the systems and technology necessary, and integrate them into the market. Specifically, further recommendations should be founded upon empirical evidence gathered from a larger body of real actors in on-field projects. This will ensure that the solutions developed reflect the needs of both the current market participants and the consumers that not are currently engaged in the market.

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Following this, the developed recommendations still require a cost-benefit analysis to help decision-makers and stakeholders navigate the transition efficiently.

Throughout the OneNet project, explicit attention is devoted to aggregation to capture its effect on opening up markets for small-scale FSPs, and the impact thereof on the efficiency of TSO-DSO coordinated flexibility market models. As a result, it is imperative for aggregation roles and remuneration mechanisms to be enshrined in regulations for all markets. By enabling aggregation, end-consumers are encouraged to participate in markets by lowering or altogether removing existing barriers such as minimum bid size or adequate market knowledge for participation. Simultaneously, clearly defined roles for existing and new market operators and a fair remuneration mechanism lowers the resistance to adopting aggregation from current market players by reducing confusion and creating financial incentives.

The addition of new market participants inherently increases the amount of data that must be managed by FSPs, aggregators, and other SOs. In tandem, the new roles require new channels for information sharing that must be managed efficiently. OneNet has proposed several solutions that address these, such as the Flexibility Register, a bid optimization tool, and a traffic light scheme to name a few. These are described in more detail in later sections of this roadmap. Moving forward, it is important that any future solution or market development aimed at improving consumer-centricity and increasing market participation should be sure anticipate the infrastructure needs and design solutions for each type of user that encourage user-friendly interfaces and facilitate communication between relevant parties.

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2.2 Products & Services

KEY MESSAGE:

New flexibility services and products for system operation are needed to address challenges due to increased uptake of RES and further electrification. In particular, services for congestion management and voltage control require development of new products. To maximize participation of Flexibility Service Providers to these new services, a harmonised product approach at EU level is needed, i.e., different flexibility products are defined according to a harmonised set of product attributes. The value of product attributes is also harmonised where possible, while considering local needs in case necessary. A harmonised product approach will facilitate coordination between system operators and integration of new services in existing flexibility markets, due to synergies where multiple system needs could be covered by similar flexibility products.

Solution:

Solution	OneNet Deliverable(s)
Theoretical framework on products	D2.2
Development of 6 harmonized products for system operation	D2.2, D3.2, D11.2
Framework for product harmonisation, including assessment of entry barriers induced by different product attributes	D3.3, D11.2

Theoretical Framework on Products

SOs use flexibility products to address long-term and short-term system needs. Multiple flexibility products exist or will be developed in the coming years, providing both frequency and non-frequency flexibility services. The OneNet theoretical framework for products defines a harmonized set of product attributes, including the range of values, that are needed to describe a flexibility product used for a specific system service.

Development of Six Harmonized Products for system operation

OneNet designed 6 common and harmonized products for system operation. These products include a locational component and can be used for both congestion management services, but also for frequency services. The harmonised products differ in timing (long-term, short-term, real-time) and in the use of active or reactive power. The products are (i) corrective local active product, (ii) predictive short-term local active product, (iii) predictive long-term local active product, (iv) corrective local reactive product, (v) predictive short-term local reactive product and (v) predictive long-term local reactive product.

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In the future, additional products for system services will be developed. To allow policy makers to assess the impact of specific design attributes on the participation of market participants and flexibility service providers, a detailed 4-step methodology has been developed to assess these entry barriers and to link them with the TSO-DSO coordination schemes to facilitated integrated markets. In addition, a general framework is proposed to continuously evolve towards more harmonised products for system services for both existing and novel services.

Enablers & Barriers:

Table 2. Table of Enablers and Barriers for the above Macro Solution. Topics are grouped into Economic (E), Regulatory (R), and Technical (T) topics.

	Enablers		**Barriers**	
	Topic	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*	**Topic**	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*
E	Stage of market development: A higher need for flexibility will lead to a more mature local flexibility market and consequently a higher need for more advanced and harmonised flexibility products	L **C** **E** S **M** L	Compatibility with product requirements from other platforms (e.g. MARI) to allow bid forwarding (value stacking) require specific product design	L C **E** **S** M L
E	Increased cross-border procurement for flexibility (MARI, PICASSO) supports harmonisation of flexibility products at EU-level.	L C **E** **S** M L	Low liquidity in local markets and limited availability of FSPs capable to follow the harmonised product requirements	**L** C E S **M** L
R	A network code for Demand Response will provide clear guidance on definition of products and services, terminology, design requirements and harmonisation guidelines.	L C **E** **S** M L	National grid code pr technical regulation puts specific limitations or requirements on flexibility services and products	**L** C E **S** M L
R	Joint incentive signals for TSOs and DSOs would support harmonisation and coordination activities, including harmonisation of products and services.	L **C** **E** S **M** L	Remuneration for system operators (TSOs and DSOs) is not aligned, resulting in different incentives for flexibility use between transmission and distribution, impacting the speed and design of flexibility services.	L **C** E **S** M L
T	The existence of common/joint or interoperable market platforms across multiple countries will provide leverage for harmonised products within and beyond national borders.	L C **E** S **M** L	The 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	**L** C E S M **L**
T	Increased information sharing between TSOs and DSOs on flexibility needs, including a dedicated communication platform supports further harmonisation of flexibility services and products.	L **C** E **S** M L	Diverging technical/grid requirements for different services for different SOs make harmonisation impossible.	L C **E** S M **L**

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Recommendations:

Product harmonization is important to support the uptake of flexibility markets, in particular due to the availability of harmonized products, more value can be attributed to the same flexibility offer as it can potentially provide multiple services in different markets. The increased value stacking potential will support the individual business cases of flexibility and accelerate the participation of flexibility in the market. Consequently, harmonized products are an enabler for coordinated and integrated European markets.

Product harmonization is applicable to existing flexibility products but should also be addressed when defining new flexibility products. In particular for services related to congestion management and voltage control, new products should be designed, including a locational component. To ensure maximum value creation from the start, the design of these new products should be maximally harmonized with existing frequency products.

To support the process of harmonization, a common terminology and classification of attributes is needed that allow a similar description of product attributes for multiple services. This common terminology should be addressed in the new Network Code for Demand Response.

Despite the important benefits of a harmonized product range, a balance should be found to address local specific needs with flexibility products that have specific local characteristics. This local need could be due to the individual characteristics of the local flexibility source or could be driven by a specific technical grid challenge.

Although product harmonization entails several benefits, it should be accepted that product harmonization will be a stepwise process due to the actual different maturity and liquidity levels of local DSO markets and national TSO markets. The kick-start of local products and markets could in some cases require adapted product design.

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2.3 Roles & Responsibilities

KEY MESSAGE:

The OneNet project recognizes the urgent need for clear roles and responsibilities for the (new) tasks and activities that emerge in the new market designs. This is indispensable to pave the way for a more inclusive and adaptable energy market, providing a leverage for future innovation projects. OneNet contributes by delivering a comprehensive framework for defining roles within the energy sector, serving as a cornerstone for business model development, data exchange efficiency, and platform standardization. OneNet ensures uniformity and clarity in role definitions, facilitating seamless information exchange and enhancing market efficiency. The framework can be used as a guideline, yet continuous review of the roles remains required in the fast-emerging market environment.

Solution:

Solution	OneNet Deliverable(s)
New or adapted role definitions	D2.5
Role definition to ensure grid-safe bid forwarding	D3.3

New or Adapted Role Definitions

In the context of the evolving landscape of market participants, new functions, tasks and responsibilities are required. This necessitates ongoing review of the Harmonized Market Role Model (HRM) to address emerging gaps. For one key gap (namely the correct modelling of TSO-DSO markets for system services), OneNet proposed new roles and responsibilities . Guidelines on both adapted roles and new roles are provided to accommodate the changing market dynamics. New definitions of roles are for example, flexibility register operator (FRO), local management system (LMS) and weather forecast provider. These guidelines on definitions of roles are indispensable to shape business models, to structure the data framework and ensure smooth flow of data among stakeholders. In addition, they play a pivotal role in achieving robust standardization of digital platforms, as seen in initiatives within the OneNet project. The exercise of defining roles and responsibilities is integral to delineating the use cases for each country and demonstration. With the OneNet guidelines and role definitions, future innovation projects can leverage this exercise early in their development to ensure alignment with European Commission mandated documents, promoting optimal coherence and effectiveness.

Commented [JV1]: Add to abbreviations

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Role Definition to Ensure Grid-Safe Bid Forwarding

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Bid forwarding is crucial in the evolving energy landscape due to the increasing availability of flexibility across different grid levels. It is crucial for enhancing the efficiency and value stacking potential of flexibility markets to allow unused bids in one market to be forwarded to another market for potential utilization. This mechanism is particularly relevant in scenarios where markets are not directly connected. Grid-safe bid forwarding is a multifaceted and intricate process, particularly when it comes to mitigating the risk of network issues stemming from forwarded bids, necessitating innovative solutions. As part of the research to provide insights into the process of bid forwarding, OneNet offers a comprehensive framework to delineate the responsibilities of the entity tasked with ensuring grid-safe bid forwarding. Overall, having an overseeing entity ensures that bid forwarding processes are conducted transparently, safely, and in compliance with regulations, thereby fostering trust in flexibility markets and promoting efficient utilization of flexibility resources.

Enablers & Barriers:

Table 3. Table of Enablers and Barriers for the above Macro Solution. Topics are grouped into Economic (E), Regulatory (R), and Technical (T) topics.

	Enablers		Barriers	
	Topic	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*	**Topic**	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*
E	Clear role definitions and an entity providing grid-safe bid forwarding can optimize resource utilization, making the implementation of the OneNet solutions more attractive by demonstrating potential cost savings.	L **S** C M **E** L	Implementing new roles and bid forwarding mechanisms may require initial investments in infrastructure and technology, posing a barrier for some market participants.	**L** **S** C M E L
E	Standardized role definitions and introduction of new roles promote market growth by facilitating transparency and trust among stakeholders, creating a conducive environment for the adoption of new solutions.	L **S** C M **E** L	Market innovations can lead to evolutions in the roles and responsibilities of certain market participants which necessitates ongoing review of the definitions to address emerging gaps.	L **S** **C** M E L
R	Supportive policies from regulatory authorities can encourage market participation and innovation in flexibility markets, driving adoption of new roles and processes by providing incentives or removing barriers for participation of flexibility.	L **S** **C** M E L	Complex or ambiguous regulations governing flexibility markets may create barriers to entry for new market participants and hinder the adoption of standardized role definitions and bid forwarding mechanisms.	L **S** **C** M E L
R	Rules/guidelines/models for aggregation are proposed in new network code demand response (draft NCDR). They should be transposed to regional regulation.	L S **C** **M** **E** L	Uncertainty regarding future regulatory changes or requirements may deter market participants from investing in new roles and responsibilities, leading to slow adoption and implementation.	L **S** **C** M E L
R	Clear regulatory frameworks that support standardized role definitions and bid forwarding mechanisms facilitate harmonization and promote market interoperability, providing a supportive environment for the implementation of the proposed solutions.	L **S** **C** M **E** L		

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T	Trainings and presentations for (new) market participants which need to take up new roles and responsibilities in which they might have little or no experience.	LS CM EL	Integrating new and adapted roles and responsibilities, including an entity for bid forwarding, within existing grid infrastructure and market platforms may pose technical challenges related to compatibility, data synchronization, and system reliability, delaying implementation and adoption.	LS CM EL
T	Dedicated platform to facilitate communication between TSOs and DSOs	LS CM EL		

Recommendations:

The definition of roles is essential from multiple perspectives. Firstly, it molds business models, particularly crucial in energy flexibility markets where these models serve as the nexus between technical innovations and economic feasibility. Additionally, in the realm of data exchange, roles and responsibilities are foundational. A well-defined framework ensures that data flows appropriately among stakeholders in the electricity market. Moreover, clear role definitions are pivotal for achieving robust standardization of digital platforms, as exemplified in initiatives like the OneNet project. This clarity facilitates seamless information exchange among participants, thereby enhancing overall efficiency.

The OneNet project leveraged the HMR and its updates proposed by the BRIDGE Regulation Working Group (HEMRM) to analyze the roles outlined in the use cases. Working collaboratively with demo partners, each role's involvement at every stage was thoroughly assessed. Once all roles were accurately defined, efforts were made to harmonize them, ensuring uniformity across all demonstrations. This harmonization enhances understanding and streamlines data exchange processes. Moving forward, it is advised that future innovation projects undertake similar exercises early in their development, aligning role definitions with European Commission mandated documents for optimal coherence and effectiveness. In addition, by leveraging these definitions and assessments, regulatory authorities can enact changes that promote the development of services outlined by the Business Use Cases (BUCs). Striving for harmonized definitions of roles and responsibilities further fosters the integration into European markets.

Aligned with discussions held within BRIDGE and the Harmonisation Group, including ENTSO-E, ebIX, and EFET, the OneNet project has introduced adaptations to existing roles, such as TSOs and DSOs, and developed new roles as well (such as the FRO). However, the analysis of these new and/or adapted roles must be thorough, ensuring avoidance of overlapping roles or deviation from EU codes and guidelines for market data exchange. The evolving landscape of market participants, necessitates ongoing review of the HRM to address emerging gaps in use cases. The OneNet project brings attention to notable proposals, like the Weather Forecast domain, underscoring the need for inclusion of additional roles at the distribution

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level, not currently addressed in the HRM. Simultaneously, the project underscores the importance of defining the entity responsible for ensuring grid-safe bid forwarding. These insights emphasize the imperative for continual refinement and expansion of role definitions to effectively capture the evolving dynamics of the energy market.

In our examination of roles and responsibilities, determining accountability for non-delivered flexibility emerged as a significant concern among most project partners. Nevertheless, the OneNet project concluded that this issue is likely to diminish in importance over time as experience is accrued and trust-based

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2.4 TSO-DSO Coordinated Flexibility Markets

KEY MESSAGE:

The volume of TSO-services procured through distribution grid connected resources has been and will further increase over the years. It is therefore important to verify whether services are not causing distribution grid constraints by increasing coordination between TSOs and DSOs. In addition, DSOs are starting to procure flexibility for system services, to resolve local problems such as voltage control and congestion management, thus resources connected in distribution grids can be used for both DSO and TSO. OneNet addresses those coordination challenges between system operators by proposing TSO-DSO coordinated flexibility markets together with frameworks to analyse their efficiency. These solutions promote efficient market models for the procurement of system services given that the different coordination market structures are conceptualized considering system operators' specific needs and restrictions. In addition, they are comprehensively analysed (procurement costs, interface flow pricing, FSPs strategic bidding, among others). As such, the TSO-DSO coordination schemes are able to maximize the value-stacking potential of flexibility (use of flexibility by multiple SOs), to return consistent and transparent valorisation opportunities to FSPs/consumers, and to ensure that the flexibility is delivered in a grid-safe manner for all participating grids.

Solution:

Solution	OneNet Deliverable(s)
TSO-DSO coordinated flexibility markets	D3.3
Framework for the Analysis of the Efficiency of Different TSO-DSO Coordinated Flexibility Market Models	D3.3
Framework for the Analysis of the Impact of FSP Strategic Bidding on the Efficiency of TSO-DSO Coordinated Flexibility Markets	D3.3

TSO-DSO Coordinated Flexibility Markets

To be able to tackle different SOs' needs and limitations, including regulatory restrictions, OneNet develops several TSO-DSO coordination processes through which flexibility from different grid levels can be provided to meet service needs of TSOs and DSOs. They differ in the way the TSO-DSO provision of flexibility resources is coordinated, such as how resources are shared between the different SOs, what are the markets' sequences, and if priority access to local resources is given to certain SOs. In one extreme, and representing current flexibility markets in Europe, OneNet proposes two disjoint schemes: (1) the disjoint central market represents a setting in which TSOs are not able to purchase flexibility from distribution networks to resolve their needs (e.g., some balancing markets in Europe), while (2) the disjoint local market symbolises the opposite case in which DSOs do

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not have access to transmission-level resources (e.g., certain local congestion management markets in Europe). On the other extreme, and representing the most efficient coordination model, OneNet proposes a common market, in which transmission and distribution system operators are perfectly coordinated and jointly procure flexibility (e.g., the Northern demonstrator of the OneNet project).

Framework for the Analysis of the Efficiency of Different TSO-DSO Coordinated Flexibility Market Models

The different TSO-DSO coordinated flexibility markets can induce varying impacts on the efficiency of the procurement process, in terms of market clearing costs, grid-safety requirements, and consumer-centricity. To analyse those efficiency parameters, OneNet develops a framework encompassing the market clearing models of the proposed TSO-DSO coordinated flexibility markets and a simulation environment enabling the quantitative comparison of those different models for multiple market clearing instances (data). As such, the developed framework is able to quantitatively investigate the sensitivity of the markets to several key factors, e.g., interface flow pricing, FSPs' bidding processes, entry barriers due to product attribute requirements, and bid formats. This allows SOs to select the best-suited TSO-DSO coordination model for their circumstances.

Framework for the Analysis of the Impact of FSP Strategic Bidding on the Efficiency of TSO-DSO Coordinated Flexibility Markets

OneNet proposes a framework to analyse the impact of FSPs' strategic behaviour on the efficiency of the TSO-DSO coordinated flexibility markets. The methodology used is based on game theory and bounded rationality to model FSPs bidding behaviour when engaging in those markets. As such, the framework is able to simulate and calculate the impact of FSPs bidding strategies on the efficiency of the different TSO-DSO market structures, identifying if certain aspects such as market fragmentation, congestions and market liquidity can lead to a higher (negative) impact on the procurement costs.

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KEY MESSAGE:

OneNet overcomes barriers related to the insufficient coordination between markets and system operators, to the lack of product harmonization, and to the absence of distribution network representation by proposing and analysing bid forwarding processes, including grid-impact aware methods. As such, OneNet ensures efficient market participation of flexibility resources from multiple voltage levels, which increases market liquidity and the value stacking of such resources, while guaranteeing a grid-safe utilisation of resources connected in other grids.

Solution:

Solution	OneNet Deliverable(s)
Grid impact aware bid forwarding	D3.3

Grid Impact Aware Bid Forwarding

OneNet proposes three different methods (multilayer market scheme, bid prequalification, and bid aggregation) to enable the grid-safe forwarding of bids from the distribution systems to deliver transmission-level services, without requiring access by the TSO to distribution grid models. Forwarding bids from distribution grid to transmission-level markets in a grid-safe way is important so that clearing those bids by the transmission-level market does not cause issues on the distribution grids (even when distribution grid constraints are not considered in the market clearing of the transmission-level market).

Enablers & Barriers:

Table 4. Table of Enablers and Barriers for the above Macro Solution. Topics are grouped into Economic (E), Regulatory (R), and Technical (T) topics.

	Enablers		Barriers	
	Topic	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*	**Topic**	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*
E	Pricing the interface flow between transmission and distribution systems can increase the efficiency of sequential TSO-DSO coordinated market models	L S **C M** E L		
R	Common types of products at both TSO and DSO levels facilitates bid forwarding	L S **C M** E L	Different types of products at both TSO and DSO levels hinder the direct forwarding of bids, leading to the need of including translation steps (e.g., extra product and grid prequalification between markets)	L S **C M** E L
R	Standard products defined at national level provide common rules for coordinated markets, especially when a large number of DSOs exist	L S **C M** E L	European dimension is needed if co-optimisation across services (i.e., common market), which is	L S C **M** **E** L

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			more cost-effective, involves balancing markets	
R		L S C M E L	In some countries, DSOs are constrained by national regulation on the establishment of flexibility markets, e.g., any purchase must be done via a "public procurement mechanism"	**L** S **C** **M** E L
T	Observable and reliable communication systems, compatible with SOs internal systems, facilitate the implementation of TSO-DSO coordinated flexibility markets	**L** S **C** **M** E L	Low compatibility between local and national actors and the data exchange tool can hinder the implementation of TSO-DSO coordinated flexibility markets	**L** S **C** **M** E L
T	Development of collaboration protocols where a common visibility is warranted without compromising the rights of protected data, especially for bid selection and bid optimisation	L S **C** **M** E L	Different market timings (e.g., day-ahead, balancing, local congestion management) can impact the feasibility of TSO-DSO coordinated flexibility markets	L S **C** **M** E L

Recommendations:

The proposition and evaluation of different TSO-DSO coordinated flexibility markets have resulted in several key insights on the adequacy of the different market formulations, leading to the following recommendations.

First, OneNet identified that a common market model, in which TSOs and DSOs jointly procure flexibility, can achieve the maximum possible theoretical efficiency, as it allows a joint and co-optimized procurement of flexibility by all SOs from a common pool of flexibility resources while abiding by all the network constraints of all the grids involved.

Second, one blocking efficiency factor in sequential TSO-DSO coordinated market models (such as fragmented and multi-level), is the interface flow. Those sequential markets involve levels of separation between transmission and distribution procurement, but, in reality, the systems are interconnected through interface lines. As such, what happens in one market level can (negatively) impact the needs of another market level (due to modifications in interface flows). OneNet shows that pricing the interface flow between transmission and distribution systems can increase the efficiency of sequential TSO-DSO coordinated market models (such as fragmented and multi-level), to the point that those markets reach solutions as efficient as in the common market (without the need of a joint procurement, which includes direct sharing of resources and possibly confidential information).

Third, entry barriers (such as minimum bid requirement) can hinder the efficiency of the TSO-DSO coordinated markets, impacting their consumer-centricity. OneNet recommends that, for instance, if minimum bid size requirements are too high (e.g., 1 MW) but mandatory (e.g., in transmission-level markets), a first market layer for small-scale resources should be added (e.g., multi-level market) as this can

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reduce the impact on the efficiency and market liquidity of the requirement.

Fourth, OneNet recommends to carefully consider which bid formats to allow/require in the TSO-DSO coordinated markets as these can also impact their efficiencies. For example, including partially divisible bids (i.e., with a minimum clearing requirement) or even fully indivisible bids has a negative impact on all market models, but the common market is less prone to that impact because it considers a larger pool of resources than other markets (i.e., it is easier to replace bids that can become increasingly expensive due to their minimum clearing constraint).

Fifth, the structure of the TSO-DSO coordinated markets can (more or less) incentivize FSPs strategic bidding. Market fragmentation (such as in disjoint and fragmented markets) is the aspect leading to a higher negative impact due to strategic behavior. As such, OneNet recommends avoiding market fragmentation (e.g., separate transmission and distribution markets) if possible.

Sixth, coordinating different markets through bid forwarding requires compatibility of the products (and their attributes), compatibility of the bid's formats, as well as a mechanism to ensure that the bids forwarded, when cleared in the subsequent market, would not cause network violations in the grids where they are located. For example, local, regional, or intrazonal network representation and constraints would not be available to the MARI platform to take them into account when procuring flexibility from those grids. As such, mechanisms to check what is the impact of clearing bids where they are located need to be implemented before forwarding them.

Finally, some incentives must be provided, and barriers must be removed to facilitate bid forwarding, such as: reducing entry barriers (e.g., through the reduction or removal of capacity reservation conditions); allowing resources aggregation; developing adequate market designs and market timings; and including simplified prequalification methods in the different markets.

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2.5 Prequalification

KEY MESSAGE:

OneNet addresses barriers related to insufficient coordination and alignment of the prequalification phase, lack of appropriate baseline methodologies, and absence of uniform registration platforms by establishing flexibility register tools as single points of contact with flexibility providers, in which prequalification and baseline activities are performed, and by proposing regulatory and harmonising frameworks for prequalification. Those solutions enhance market alignment and support efficient flexibility provision.

Solution:

Solution	OneNet Deliverable(s)
Flexibility register	D3.2, D7.2, D8.2, D10.3
Framework for regulatory options for prequalification	D3.4
Framework for harmonising prequalification	D11.2

Flexibility Register

A flexibility register (FR) stores, manages, and shares all relevant information on potential resources participating on flexibility markets. In OneNet, the FR is responsible for the prequalification process, where the FSPs are registered, where their prequalification is done according to predefined requirements, and the activated services and resources are stored. It can also contain other functionalities related to other market phases (e.g., verification and settlement), such as contract management, determination of the actual delivered flexibility quantities, and baseline calculation. The FR is closely integrated with TSO-DSO coordination platform and Market operator platforms to enable a well-functioning local flexibility market. Three demos include a type of flexibility register: the Northern, the Czech and the Greek. The Northern demo establishes its flexibility register as the single point for product prequalification, prequalifying FSPs' resources and resource groups according to the harmonised products' requirements. In the Greek demo, the flexibility register is integrated within its F-Channel tool, and the same (standardized) registration format is used for all assets (including resources' location and other eligibility criteria). As such, the prequalification is simplified and is done only once upon the standard registration of each FSP. The Czech demo opts for a simpler approach, with a database comprising the activated services, including a common procedure for the registration of platform users.

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Framework for Regulatory Options for Prequalification

OneNet proposes a four-question framework relevant for the (further) development of regulation for prequalification. Questions are related to i) whether prequalification should be mandatory; ii) who is the responsible party; iii) where are the eligibility criteria set; iv) how the submission of the prequalification template should be done. The framework was applied to the OneNet demonstrators. For the first question, all of them considered prequalification a mandatory process that cannot be replaced by an ex-post verification. Although the FWGL DR recommends applying ex-post verification by default, the demos considered, tested, and advised the ex-ante option due to system security and reliability reasons (mainly). For the second question, the actor responsible for the prequalification process varied, i.e., DSO/TSO/FRO for the Northern demonstrator, TSO/DSO for Greece, Portugal and Slovenia, DSO for Cyprus, Hungary and Czech, and DSO/IMO for Spain and Poland. It is important to notice that different responsible parties in the same demo are responsible for different types of prequalification (product or grid). For the third question, most of the demonstrators defined eligibility criteria at platform level. Only the Northern demo set those at market level, mentioning that they should be established in the law by the regulator or by the respective SO. For the last question, a trend is seen among the demonstrators to use a dedicated platform to communicate prequalification results to market participants (i.e., Northern, Greece, Portugal, Spain, Czech, Slovenia, Poland). However, other means were also used, as e-mail (i.e., Cyprus, Spain, Hungary) and the OneNet System (i.e., Cyprus, Spain, Portugal).

Framework for Harmonising Technical Prequalification

OneNet assessed the potential for harmonising the technical prequalification phase in the demonstrator solutions. In a first step, principles and practices for the design of the technical prequalification procedure were defined and scrutinised, which involved the analysis of external recommendations for simplifying the prequalification (e.g., ex-post prequalification, sharing the burden of prequalification according to the size and risk of the resource, common pre-qualification for multiple SOs procuring the same product, etc.). Then, the demonstrator designs for prequalification were analysed, which considered three dimensions: the harmonisation of prequalification procedures for multiple products, System Operators (SOs), or considering Service Provider (SP) units and groups. Next, the barriers for large scale adoption of OneNet solutions on harmonised prequalification procedures were analysed. In addition, the demo design drivers for large scale harmonised prequalification procedures adoption were analysed. Finally, a risk assessment of prequalification-related topics was performed. The framework resulted in a set of recommendations and best practices for harmonising prequalification phases.

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Enablers & Barriers:

Table 5. Table of Enablers and Barriers for the above Macro Solution. Topics are grouped into Economic (E), Regulatory (R), and Technical (T) topics.

	Enablers		Barriers	
	Topic	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*	**Topic**	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*
E	Streamlined processes, unified at the national market level, which contain clear simplification for small units (e.g., connected to low voltage), reducing their cost to participate	L S **C M** E L	The cost sharing structure on the activation tests and certification processes of prequalification can hinder the participation of smaller resources	L S C M E L
R	Clear definition of transparent and uniform procedures across services at national level (in line with EU guidelines), including prequalification specifications in DSO network code and the definition of local flexibility markets	**L S** C M E L	Large number of DSOs, with different owners, makes aligning on common rules for prequalification difficult	L S **C M** E L
R	Harmonisation of rules for flexibility register and interoperability, specially at national level	L S **C M** **E L**	No defined governance between TSO/DSOs for flexibility register, as well as agreeing on governance of regional/cross-border register	L S **C M** E L
T	Availability of coordinated and/or harmonised tools to facilitate registering and prequalifying resources (OneNet Framework)	L S **C M** **E** L	If prequalification integration procedures are too complex, it might be more efficient to keep them separate, especially for DSOs in the short term	**L S** **C M** E L
T	Advanced IT systems that process large datasets, employ analytics, provide insights on the entire portfolio, and are compatible with SO systems (a must have infrastructure for each operator at each country)	**L S** **C** M E L		L S C M E L
T	Embedding grid qualification in bid optimization process, in a way that the most adequate information about the grid impact of the combination of selected bids is considered	L S **C M** **E** L		L S C M E L

Recommendations:

The proposition of flexibility register tools together with a regulatory framework for prequalification have resulted in several key insights on how to enhance the alignment of market phases and on how to improve the efficiency of flexibility provision.

First and foremost, the simplification and harmonisation of prequalification processes can be successfully achieved through flexibility register tools. As a single point of contact between the market and the FSPs, the flexibility register contains all the needed information for prequalification procedures, which can be automatically performed for the resources interested in providing flexibility, for multiple system services at once. Moreover, with the inclusion of harmonised steps for the prequalification of resource groups, smaller units can be aggregated and reach product specification/attributes (such as minimum size), enhancing the liquidity, consumer engagement, and consumer-centricity of such markets.

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Through the OneNet Frameworks for Prequalification, the OneNet project identified that the majority of entities responsible for the prequalification process do not feel prepared to apply an ex-post verification instead of an ex-ante prequalification, as proposed by ACER in 2022 in the FWGL DR. This ex-post simplification to the prequalification process, although interesting to increase consumers' participation and to harmonise the prequalification of specific balancing, congestion management and voltage control products, can jeopardize service reliability as well as lead to non-delivery of procured services (resulting in FSPs' penalisation). As such, the OneNet project recommends a careful design of the prequalification process allowing the responsible entities to opt for an ex-ante process under certain technical criteria, which should be defined in the actual network codes.

Moreover, some of the OneNet demonstrators proposed the option of embedding the grid prequalification in the trading phase to address the challenge of prequalification timing when coordinating markets. This approach can make the process more dynamic, allowing for adjustments based on real-time grid conditions and validation processes, leading to a more efficient system.

In addition, the OneNet Frameworks identified the main regulatory options for determining the responsible entity for carrying out the prequalification process as the SOs, coordinated efforts between TSOs and DSOs, the IMOs, and a combination of entities influenced by local regulators, market frameworks, and stakeholder engagement. Each option brings specific advantages, such as data confidentiality, technical expertise, system knowledge, market experience, neu jeopardize service reliability as well as lead to non-delivery of procured services (resulting in FSPs' penalisation). As such, the OneNet project recommends a careful design of the prequalification process allowing the responsible entities to opt for an ex-ante process under certain technical criteria, which should be defined in the actual network codes.

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In addition, the OneNet Frameworks identified the main regulatory options for determining the responsible entity for carrying out the prequalification process as the SOs, coordinated efforts between TSOs and DSOs, the IMOs, and a combination of entities influenced by local regulators, market frameworks, and stakeholder engagement. Each option brings specific advantages, such as data confidentiality, technical expertise, system knowledge, market experience, neutrality, and understanding of market dynamics. As such, the OneNet project recommends that the choice of the responsible entity should consider these factors to ensure fair competition, reliable market outcomes, and the effective evaluation of resources' capabilities. Moreover, establishing coordinated procedures across SOs and FSPs for prequalification is essential for resources aggregation (especially within different grids).

Also, the same Frameworks determined the main regulatory options to set the eligibility criteria for flexibility sources as the platform level, the market level or a hybrid option. Setting criteria at the platform level ensures consistency, transparency, and adaptability, which can help lower entry barriers. Conversely, setting criteria at the market level avoids prequalification duplication and promotes market efficiency. However, both options need to carefully consider the potential risks of market fragmentation. As such, the OneNet project recommends that the choice of the appropriate level should consider the trade-offs between consistency and flexibility, duplication and efficiency, adaptability, and market fragmentation, while ensuring fair competition, transparency, and a reliable market outcome

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2.6 Procurement

KEY MESSAGE:

EU regulations advocate for a market-based approach to procuring flexibility for system and grid services. The success of this approach is contingent upon the development of efficiently functioning flexibility markets, which can reliably deliver the needed flexibility at minimized costs. This necessitates having:

(1) **Well-structured and coherent market designs** that serve as blueprints for establishing flexibility markets, enabling replicability, and thereby reducing implementation costs,

(2) **Development of TSO-DSO coordinated market platforms** which enable the participation of the different stakeholders in the market and the coordination of the procurement process between TSOs and DSOs to maximize the value stacking potential of flexibility and minimize the risks of unintended network issues arising from flexibility activation outside from grids outside an SO's area of control,

(3) **Cost-effective system and grid flexibility needs' fulfilment**, guaranteeing that the system and grid needs are met reliably and at minimum costs, while ensuring fair remuneration to FSPs, and

(4) **Effective coordination among flexibility markets and with existing wholesale markets**, which supports the synergistic operation of the different markets, enabling the SOs to more accurately estimate the needs of their systems at different time stages and FSPs to participate efficiently in different markets.

These core aspects are a primary focus within OneNet for which concrete solutions have been developed and implemented.

Solutions:

Solution	OneNet Deliverable(s)
Theoretical market framework for existing and novel market design	D3.1
Market (TSO-DSO coordination-enabled) platforms	D9.4, D7.4
Optimization-Based market Clearing Engine	D7.4
Gate closure coordination	D3.2, D3.3, D11.2
Bid forwarding processes analysis	D3.3, D11.2

Theoretical Market Framework for Existing and Novel Market Design

To support the design of an efficient, integrated, and scalable market for the procurement of system services, OneNet proposes a theoretical market framework for existing and novel market design options aiming at classifying/categorizing different flexibility market concepts and facilitating the communication on these concepts.

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The market framework development has built upon previous market concepts and coordination models defined in previous European projects. The framework is based on five key pillars, including:

1. **Entire market architecture** pillar capturing different features such as:
    a. Number and timing of sub-markets,
    b. The products and services traded,
    c. The level of locational granularity adapted as well as the system operator and grid voltage levels involved,
    d. The specific roles of the different actors, specifying the primary buyers and sellers of flexibility and the market operator.
2. **Sub-market coordination** pillar capturing different features such as:
    a. Overall allocation principles of flexibility, which includes aspects related to how flexibility is allocated among the different markets, the ability of forwarding of bids between markets, and the access by SOs to flexibility from outside their systems.
    b. Timeframe for coordination, which captures the coordination phase between sub-markets.
3. **Market optimization** pillar capturing aspects relevant to:
    a. The methodology employed for market optimization
    b. The market optimization strategy in terms of temporal dependence/independence among different optimization runs
    c. The optimization objective for market clearing including cost reduction and social-economic welfare maximization.
4. **Market operation** pillar, capturing aspects relevant to:
    a. The remuneration scheme in place.
    b. The product attribute on which the remuneration is based.
    c. The type of market clearing mechanism (e.g, continuous markets vs. auction-based discrete markets).
    d. The procurement temporal frequency.
5. **Grid constraint representation** pillar, which captures features relevant to how the grid constraints are modeled and included in the market clearing process, focusing, e.g., on:
    a. The methodology adopted for grid constraint representation,
    b. The timing of grid constraint inclusion (pre-qualification, during procurement phase, or ex-post during the activation phase).

The development of those pillars aims at classifying the interconnection and interaction that can take place between different submarkets leading to a comprehensive architecture capable of describing the various elements of flexibility market settings. Pillar 1 explores the complete market architecture, while Pillar 2 focuses on the coordination between the sub-markets. Pillar 3 focuses on the optimization for market clearing purposes,

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while Pillar 4 focuses on market operational dimensions. Pillar 5 focuses on the representation of grid constraints within the market.

The theoretical market framework was applied to classify the market designs within the different OneNet demonstration clusters, leading to 3 different market schemes:

1. **Market-based TSO-DSO coordination** model, capturing a setting in which TSOs and DSOs coordinate their procurement of flexibility,
2. **DSO market-based** model, capturing the setting of local markets in which a DSO procures flexibility from locally connected resources to meet local grid needs, and
3. Technical-based TSO-DSO coordination model, which focuses, in particular, on the direct communication and interaction between TSOs and DSOs (including the interaction between control centers and platforms) for flexibility allocation.

Market (TSO-DSO coordination-enabled) Platforms

OneNet has developed several market coordination platforms. These platforms provide an interface to the different actors to act in the market (system operators, flexibility service providers, market operators, flexibility register operators, etc.), submitting their information to the market (e.g., bids, flexibility needs, purchase offers, etc.), and receiving the market outcomes (and at instances activation requests) through the platform. These platforms can act as a market platform within a single market operator, or can be coordination platforms allowing multiple MOs to connect to and use the platform. The platform can also either integrate different functionalities such as the flexibility register or can connect to modules at the SOs, MOs, FSPs/aggregators, and optimization operators' sides. Different demos in OneNet have adopted different platforms. However, cross-interconnection is made possible through the interconnection of these platforms to the OneNet middleware, supporting interoperability/scalability and the role of OneNet to advance interconnected, harmonized solutions. Next, two examples of platform developed within OneNet are highlighted, one from the Western demo cluster consisting of a local market platform and one from the northern demo cluster consisting of a Transmission-distribution coordination platform.

Example from the Western demo cluster:

In the Spanish demo of the Western demo cluster, OneNet has developed a local market platform enabling the DSO to procure flexibility from locally connected resources. The platform is run by an independent market operator and serves as an interface for the different market participants. The local market platform receives the flexibility needs of the DSOs, the bids from the FSPs, clears the market, and communicates the results to the different stakeholders. The platform would open a flexibility market session in an event-based manner,

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depending on the arising need at the DSO side. The traded product are active/power energy products and correspond to: predictive short-term local active product, a predictive long-term local active product, and a corrective local active product, including reservation/availability and activation dimensions, with different remuneration mechanisms for flexibility and activation.

The local market platform also acts as a flexibility register allowing the DSOs to know the number and types of flexibility resources that are available, in addition to their location and other technical information.

Demonstrated as part of the Spanish demo, the LMP then:

- Enables stakeholders to interface with the local market,
- Allows DSOs and IMO to determine resource availability and relevant technical information thereof,
- Enables flexibility procurement by DSOs, by opening a market session when needed.
- Collects FSPs bids and DSOs flexibility needs.
- Clears the market and communicates market results to the stakeholders.

Example from the northern demo cluster:

In the northern demo cluster, a transmission-distribution coordination platform was developed to support TSO-DSO coordination for the procurement of flexibility services (congestion management) through the trading of different flexibility products (long-term, short-term, near real-time, as well as capacity and energy products).

The platform provides several key functionalities, such as:

- Enables the coordinated procurement of flexibility between TSOs and DSOs and supports the run of a joint flexibility market as well as local markets,
- Provides initial flexibility resources grouping and their grid qualification,
- Enables SOs to initiate call for tenders,
- Develops and integrates flexibility register functionality (flexibility register as an integrated component)
- Receives FSPs bids, system operators' needs/system models, and purchase offers needed for the market runs,
- Coordinates and integrates those inputs to be then sent to the market clearing engine for running a joint, common flexibility market (i.e., the optimization module),
- Receives the market outcomes from the optimization module and sends the market results to the SOs, MOs, and FSPs leading to sending activation signals to flexibility resources,
- Enables connection to a market clearing engine (i.e., the optimization module),
- Provides connection possibility with the OneNet middleware,
- Provides connection possibility with EU platforms (e.g., MARI).

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This ICT platform enables the successful trading of different flexibility products in the Northern demo cluster in OneNet, in which TSOs and DSOs from Finland, Estonia, Latvia, and Lithuania have run specific use cases in support of their systems. The platform enabled connection to the optimization module/market clearing engine operated by VITO, as well as to market platforms such as Nordpool and Picloflex, in addition to a connection to other OneNet actors through the OneNet middleware.

Optimization-Based Market Clearing Engine

OneNet highly focusses on joint TSO-DSO procurement of flexibility products by developing a bid optimization tool that matches flexibility bids and purchase offers in the most economical way, taking into account not only each bid's price, but also its impact on each network component.

Indeed, OneNet developed a market clearing engine, dubbed "**optimization-based market clearing module**" which enables jointly meeting the flexibility needs of TSO and DSOs, maximizing the flexibility value stacking potential and minimizing flexibility procurement costs. The module maximizes procurement efficiency (minimizes procurement costs, equivalently, maximizes the social economic welfare), while meeting the grid operation limits and abiding by the submitted bids technical needs. Indeed, the optimization module aims at not only resolving the grid/system flexibility needs (e.g., congestion management) at least possible costs, but also ensures that the cleared flexibility, when activated, does not cause grid operational constraint violation in any of the grids involved. The module takes as inputs:

a. The set of flexibility bids submitted and their technical requirements (accepts different types of simple and complex bids – in harmonization with MARI bid requirements – namely, fully divisible, fully indivisible, partially divisible, multipart (parent/children), and exclusive set bids),
b. The system operators' network information (highlighting the network configuration, power transfer distribution factors, expected power flows, and line limits), and
c. A purchase offer containing fundamental information provided by the SOs to launch the market clearing process and the procurement of flexibility, while indicating limits on the impact congestion management can have on the system balancing state.

The key outputs of the module include:

a. The portion of each bid to be cleared/purchased,
b. The total flexibility procurement costs, and
c. The updated network state including flexibility activation (i.e., the updated power flows, imbalance position),
d. among others.

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The module enables the optimal trading of different flexibility products, namely:

a. Near real-time active energy (NRT-P-E),
b. Short-term active energy (ST-P-E),
c. Short-term capacity (ST-P-C),
d. Long-term capacity (LT-P-C),
e. Long-term capacity with activation stage (LT-P-C/E-res is the product for the reservation stage and LT-P-C/E-act is the product for the activation stage).

It is automatically usable and accessible through a developed API. For the NRT-P-E product, the module also allows linking with MARI for the forwarding of flexibility bids from the regional flexibility platform to MARI. The forwarding of bids undergoes first a **MARI check** and a **grid check** filtering process to ensure, respectively, that the forwarded bids abide by MARI's bid requirements, and that the forwarded bids do not risk causing constraint violation to the local grids, from which they originated, if activated by MARI.

The optimization module has been thoroughly and successfully tested and demonstrated in the northern demo cluster. The module reliably returned the market clearing results in a very short period of time (<0,25 s in all tested demo cases, in Finland, Estonia, Lithuania, and Latvia), ensuring an achieved minimum procurement cost and ensuring grid safety given the available sets of flexibility bids made available to the market.

Gate Closure Coordination

As highlighted by several OneNet demo clusters, gate closure time (GCT) incoordination is a main barrier for flexibility market integration.

Market gate opening and gate closure times directly impact whether FSPs can have the chance to use their flexibility in subsequent markets in case they were not cleared in preceding flexibility markets. In addition, having significantly early GCT can result in large uncertainty for the FSPs coupled with significant forecast errors, which influences their participation and the reliable service delivery to the grid, which in turn impacts the flexibility needs in subsequent markets. Indeed, improper coordination among GCTs has been identified by the OneNet as one of the main barriers facing bid forwarding.

OneNet highlights that gate closure times of flexibility markets must be coordinated properly, while taking into consideration existing energy markets, to (i) better estimate the evolving network state and flexibility needs, which in turn can be accommodated by flexibility products, and (ii) to allow transparent market participation for FSPs, enabling them to valorize their flexibility, thus achieving increases in revenues and/or cost reductions,

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while concurrently benefiting the system. Indeed, coordinated GCT enables FSPs to maximize the value stacking potential of their flexibility by enabling them to subsequently bid in different markets.

GCT coordination can capture:

- Coordination among the gate closure times of the flexibility and services markets in place.
- Coordination with existing energy markets (e.g., day-ahead and intraday markets)

Different demos in OneNet have followed different approaches in coordinating the GCTs of their implemented markets. Some examples, among others, are highlighted next to showcase different variants:

- In the Northern demo: a GCT coordination is established to support the effective trading of the different flexibility products, considering the flexibility services that these products provide (i.e., coordination of the trading of the different flexibility products from long-term, to short-term, and near real-time. This coordination also considers coordination of the flexibility markets with respect to the wholesale markets (DA and ID) and balancing markets (e.g., MARI). For example, the Northern demo adopts a coordinated trading of its short-term active energy product (ST-P-E) with the wholesale intraday market. This is readily possible as the ST-P-E trading is integrated within the intraday market trading of Nordpool through what is referred to as locational intraday trading (intraday energy exchange with locational information enabling SOs to purchase ID bids for flexibility procurement). The GCT of ST-P-E trading is fixed at 2 hours before real-time. On the other hand, the GCT for the near real-time active energy product (NRT-P-E) is much closer to real-time operation and is set at 25 minutes ($T_0 - 25$) before real-time (T_0). This enables the operator to have a more complete knowledge of the network state (e.g., power flows), which considers the activations resulting from the ST-P-E product trading, hence allowing a better use of the NRT-P-E product. In addition, the 25 minutes GCT coincides with the balancing service providers' (BSPs) GCT within the MARI platform. As such, at T_0-25min, the BSP would in any case send their flexibility bids to the TSO, so this can be done in a joint manner where flexibility can be used for congestion management first (if desired by the FSP) before it being considered for balancing within the MARI platform. Moreover, the bids to be forwarded to MARI in the NRT-P-E case, must be forwarded latest 12 minutes before real time (T_0-12min). This has the goal to have those bids considered for scheduled activation (SA) by MARI, whose GCT for TSOs is at T_0-10min.
- The Polish demo has established a setting in which all bids related to congestion management and voltage control at the distribution grid level are to be submitted and cleared before the gate closure time for balancing capacity.
- In the Cypriot demo for FCR products, bids are first cleared in the TSO market. The remaining active power flexibility from FSPs connected in the distribution grid can then be traded subsequently in the local DSO near real-time market.

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The coordination between the gate closure and opening times of the markets enable flexibility providers to effectively participate in the different possible markets to maximize their valorisation potential. This can be further supported by an automatic forwarding of bids from one market to the other, i.e., when bids of an FSP are not cleared in one market (e.g., local congestion management), they will be automatically forwarded to a following market to be considered for market clearing there (e.g., in the balancing market). This concept is referred to as "bid forwarding", which can enhance the revenue stacking of service provides and the market liquidity. OneNet introduced a definition of bid forwarding and proposes a methodology to analyse different bid forwarding processes through which one can effectively assess the bid forwarding potential and address hindering barriers for its implementation in the markets.

Enablers & Barriers:

Table 6. Table of Enablers and Barriers for the above Macro Solution. Topics are grouped into Economic (E), Regulatory (R), and Technical (T) topics.

	Enablers		**Barriers**	
	Topic	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*	**Topic**	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*
E	Several demo activities have already run in Europe, which provides a background experience and available solutions for implementing flexibility market procurement processes leading to reduced costs. Continuous support for these demo activities, focusing on scalable and replicable solutions, at the European, national, and regional scales can support the continuous decrease in development and implementation costs.	**L** **S** **C** M **E** L	High costs of development and implementation of market platforms which can at instances disincentive flexibility market implementation as compared to other flexibility procurement options or grid investments. Even though the costs are decreasing due to gained experience and replicability potential, the costs for different operators can still be perceived to be high. Short to medium term support on the European scale through demonstration projects can contribute to driving down such implementation prices. High implementation costs can imply high participation costs for stakeholders, which can be a deterrent for participation.	L S C **M** E L
E	Implementation of optimization-based market clearing mechanisms (which not only consider the costs of the bids submitted, but also their impact on the different grid elements and their ability to effectively contribute to the flexibility need) can achieve minimized costs to the SOs and fair and transparent remuneration for the FSPs. This acts as an economic enabler for	L **S** **C** M E L	Low liquidity challenges may hinder the realization of the efficiency potential of flexibility market procurement processes. This is in general a barrier for flexibility markets, and not just specific to the procurement processes.	L **S** **C** M E L

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	the implementation of these mechanisms as compared to simple merit-order based clearing that only considers the bid costs. In addition, engagement mechanisms to support the widescale participation of FSPs in those markets, would help such market schemes achieve their potential.			
R	There is a general regulatory support for market-based procurement of flexibility, and the efficient functioning of markets, and for making the systems and markets ready to integrate demand side flexibility, as seen by the ongoing network code on demand response. Hence, a reassessment of regulatory mechanisms at the member state level, in accordance with EU regulation., would support the realization of these initiatives.	L **S** C M E L	In a number of EU countries, development of market mechanisms at the distribution level is still currently limited by regulation.	L **S** C M E L
R	There is a general support for harmonization potential between markets at the European level, when feasible. These efforts can aim to address when harmonization or coordination would be beneficial and when not, which can support the coordination between different flexibility markets. The rise of European platforms for balancing services, and the ongoing integration of EU wholesale markets, provides a common reference for the timing of those markets and their coordination, which can then be used for the design of local/regional markets for other flexibility services (e.g., congestion management) to ensure the possible coordination among those markets.	L S C **M** E L	Different SOs and different countries can have their own set of regulation and services needs which limits the possibility of modifying gate opening and closing times for different markets to accommodate market timings in other countries or for other SOs. This can also be a challenge whenever harmonization of product requirements is needed for bid forwarding.	L S C M E **L**
R	Enabling the use of "free bids", i.e., bids from capacity not previously reserved, in addition to bids from reserved capacity can enable the use of bid forwarding.	L S C **M** E L	Some markets require capacity reservation conditions to be able to participate. This process can hinder bid forwarding potential.	L S C **M** E L
R	Implementation of coordinated or common prequalification mechanisms for different markets can support the participation potential of an FSP in all these markets while reducing the organizational burden. This, as a result, enables	L S C M E **L**	Each market normally necessitates pre-qualification of its resources (with respect to their ability to provide the service and to participate in the market). When considering the forwarding of bids between market, the FSP has to go through the prequalification process multiple times, once for each market, which	L S C M E **L**

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	the implementation of bid forwarding between markets.		can increase operational cost and the complexity of participation.	
T	There is a large technical knowhow in the different European counties on setting up flexibility market procurement processes/platforms, which is gained through several demonstration projects and local/national initiatives. In addition, the coordination between different flexibility markets has also been addressed in OneNet, where common platforms were also developed. Such coordination can be facilitated through support at the European level, thus enabling the implementation of coordinated and interconnected flexibility procurement processes and platforms. Support in platform development enabling the unlocking of economies of scale when setting up a common market platform can also provide incentives for different SOs and MOs to join forces, while reducing the perception of additional complexities or costs.	L S C M **E** L	Market coordination platforms not only require high level of ICT expertise but also requires the ability to seamlessly connect with other platforms developed in different countries, to support wide-scale accessibility to flexibility in different grids. Such technical requirements can be difficult to achieve specially in the absence of continuous coordination among the stakeholders. In addition, setting up common platforms can be perceived as complicated and time consuming.	L S C **M** E L
T	Technical support and engagement with the operational and planning departments of the SOs would be needed to support the generation of the required network representations and models to be integrated in local, central, or TSO-DSO coordinated market clearing formulations.	**L** **S** C M E L	Efficient and grid-safe TSO-DSO coordinated procurement processes require SOs to generate and communicate/share needed network data and models for flexibility market optimization and clearing. Such network model generation and representation may not always be available.	**L** **S** C M E L
T	Optimization linearization/convexification techniques and computationally efficient methodologies are widely available and can be implemented to support the efficient and timely market clearing, targeting computational complexity challenges that such markets can face, when considering very large systems and the introduction of complex bids.	**L** S C **M** E L	Optimization-based market clearing mechanism can face computational complexity challenges, especially when considering the introduction of complex bids and very large systems.	**L** S C **M** E L

Recommendations:

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The market-based procurement of flexibility for system and grid services requires the development of efficiently functioning flexibility markets, capable of delivering the needed services reliably and at minimum costs. The following key recommendations enable achieving those goals.

Flexibility markets, and market platforms therefor, can be perceived to be a new type of markets for SOs and solution providers, which implies additional complexity and costs of implementation. These implementation costs can be prohibitive and can disincentivize the setting up of these markets when compared with other flexibility procurement options and grid investments. However, several flexibility markets have already been implemented in demonstration activities (in European and national projects) and actual operation across Europe. These previous experiences can enable the replicability/scalability of those solutions or can, at minimum, provide guidance on how to set up those markets not to need to start from scratch with every new flexibility market initiative. As such, making use of previous experiences, and supporting this transfer and build-up of knowledge through BRIDGE initiatives, common workshops, and/or direct cooperation between the partners in European projects would help reduce the perceived high investment costs as well as the complexity of implementation and operation of flexibility markets and their platforms.

Setting up TSO-DSOs coordinated market platforms support the coordination and concurrent participation of different stakeholders (buyers of flexibility, such as TSOs and DSOs, market operators, FSPs, flexibility register operator, market optimization operator, etc.). This enables a common interface for these actors as well as the coordinated and grid-safe procurement of flexibility between TSOs and DSOs, and the maximization of the value stacking potential of flexibility. However, this does not always mean that a single market platform should be set up. Different platforms can be set up to accommodate the needs of different SOs and their service requirements, and the practical setting of the grids for which these markets are implemented. However, these market platforms should be enabled to seamlessly interact, thus enabling access to a wider pool of flexibility, as well as coordination between SOs to align on the flexibility needs and minimize the risks of unintended grid consequences stemming from flexibility activation.

Implementation of intelligent optimization mechanisms for market clearing (referred to in the context of OneNet as optimization-based market clearing mechanisms) enable clearing the flexibility market while ensuring minimum costs for the SOs and fair remuneration for FSPs (maximization of social-economic welfare), while considering not only the costs of the bids to be cleared but also how they would impact the operation of the grid (as this would capture the real cost of purchasing a flexibility bid) to capture: 1) their impact on resolving available grid issues for which the market is set up, and 2) ensure that this flexibility procurement does not lead to additional issues in any of the grids involved. Hence, including the grid aspect in the market clearing process (going beyond simple merit-order lists for market clearing) is essential to capture these elements, thus achieving a truly optimal market output. OneNet has demonstrated the success of using such optimization-based market clearing mechanisms (e.g., through the optimization module developed and tested in the Northern demo cluster). The implementation of these optimization mechanisms can act as enablers for participation as it brings benefits to both SOs and FSPs. Here, in case computational complexity of these techniques becomes challenging, developers are encouraged to make use of the wealth of solutions available in the operations research literature and in practice, and which are capable to reduce the possible computational load of these mechanisms.

The implementation of TSO-DSO coordinated markets, and the integration of grid representations, can constitute a participation challenge for SOs due to the need to generate the grid models/representation required and the sharing of this information. Here, it is recommended for platform developers as well as the developers of market-clearing engines to support the operational and planning departments of system operators in generating the needed data and its communication following standardized data models (e.g., CIM). In addition, security and confidentiality guarantees should be in place to secure the shared data. In addition to cybersecurity and encryption measures, abstracted forms of grid data can be used if the flexibility needs of the system allows it. For example, if an area of the grid is known and guaranteed to have overcapacity without any risk of congestions and voltage issues, the representation of that grid section in the market clearing formulation can be abstracted.

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To maximally capitalize on the use of these TSO-DSO coordinated flexibility market platforms and the benefits introduced through optimization-based market clearing mechanisms, the engagement of FSPs is needed to support and sustain a high level of liquidity in those markets. As such, engagement processes to highlight the benefits of valorising flexibility is essential to engage FSPs and incentive their participation in the markets. Transparent and efficient market functionality brought forward through these platforms and market clearing mechanisms are also a main incentive for FSP participation.

In addition to the coordination within market platforms, coordination between the different flexibility markets that are set up is also essential to enables the SOs to define their flexibility needs more clearly (taking into account the effects of flexibility activations in other markets), and for FSPs to maximize the valorisation of their flexibility through the ability to participate in different markets. Essential elements therefor consist of coordinating, as much as possible the temporal sequence of these markets, e.g., their gate opening and closing times, as well as coordinating their participation requirements, enabling FSPs to more easily participate in those different markets. For example, coordinating different markets through bid forwarding requires compatibility of the products (and their attributes), compatibility of the bid's formats, as well as reducing the requirement on capacity reservation for participation (i.e., supporting the use of free bids), and the harmonization/coordination of the prequalification processes (i.e., through joint or common prequalification processes among different compatible markets), enabling FSPs to participate in those different markets through a simple bid forwarding mechanism.

In this regard, a general support on the EU level exists for harmonization between markets, when this harmonization brings tangible benefits. In addition, the development of European-scale balancing platforms (i.e., MARI, PICASSO, TERRE), and the ongoing integration of EU wholesale markets, sets a common reference allowing the alignment of newly developed flexibility markets to ensure their possible coordination with those markets. In addition, existing markets are also encouraged to take into account the arising flexibility need in the European grids (transmission and distribution) and adapt their processes in support of flexibility procurement. For example, OneNet explored the introduction of locational granularity in intraday wholesale markets enabling SOs to purchase bids from those markets that are deemed to support their grid (the ability to provide that support is reflected through the bid's locational dimension).

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2.7 Settlement & Baselining

KEY MESSAGE:

OneNet emphasizes the importance of selecting the right baseline methodology for flexibility services, considering simplicity, accuracy, and integrity. Ultimately, the selection of a methodology depends on various factors, including stakeholder expertise, regulatory parameters, and available resources. OneNet offers practical insights and a framework for this selection process. Baselining methods are identified as a pivotal solution area within the project, with a focus on harmonization, standardization, or coordination across different voltage levels and markets. Alignment across different settlement and baselining methods is crucial to streamline processes and ensure accurate measurement and settlement of flexibility, particularly in emerging markets and at the low voltage level.

Solution:

Solution	OneNet Deliverable(s)
Framework for regulatory options for baselining	D3.4, D11.2
A concrete method to define the baseline	D3.2

Framework for Regulatory Options for Baselining

A comprehensive taxonomy of baseline methodologies reveals their varying performance across the three pivotal principles of baselining: simplicity, accuracy, and integrity. While no baseline can perfectly embody all three principles due to their inherent nature as estimations, those striking a balance among them are deemed superior. Consequently, selecting the optimal baseline methodology is a nuanced process, contingent upon factors such as the type of the provided service or product, characteristics of the service provider, timeframe, and relevant requirements and regulations. Introducing a six-question framework within the OneNet project elucidates regulatory options concerning baselining methodologies: (1) the considered relationship, (2) grid operational state, (3) responsibility for baseline setting, (4) customer type, (5) DER type, and (6) applicable product. Each question in the framework is accompanied by a range of potential answers, deliberated with a keen focus on the baselining principles and its objectives of accurate verification and settlement. These insights, gleaned from the OneNet demonstrators, furnish a practical framework for evaluating the most suitable option.

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A Concrete Method to Define the Baseline

A precise definition of a baseline is crucial for verifying the provision of flexibility services. With numerous methodologies available for calculating baselines, it is acknowledged that a degree of harmonization is essential to expedite DR development and lower barriers for new entrants in electricity markets. The OneNet project offers an overview of baseline definition methods, enriched with insights from demonstration projects for practical implementation. Diverse settlement methods can lead to inefficiencies and increased costs for FSPs, navigating multiple procedures with underlying uncertainty regarding future collected revenues from flexibility delivery, emphasizing the need for alignment to streamline processes and ensure accurate measurement and settlement. While different services may have unique baselining requirements, the options presented within the OneNet project allow for seeking synergies between markets and potentially mitigating these discrepancies.

Enablers & Barriers:

Table 7. Table of Enablers and Barriers for the above Macro Solution. Topics are grouped into Economic (E), Regulatory (R), and Technical (T) topics.

	Enablers		**Barriers**	
	Topic	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*	**Topic**	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*
E			Without transparent baseline methodology, the revenue stream for FSPs are uncertain.	L **C** E **S** M L
E			The need to upgrade systems and infrastructure to accommodate standardized baselining and settlement processes may incur initial implementation costs for market participants, especially smaller entities with limited resources.	L **C** E **S** M L
R	Regulatory framework for baselining is proposed in new network code demand response (draft NCDR). This should be transposed to regional regulation.	L C E S M L	Large number of DSOs makes aligning on common rules difficult.	L **C** E **S** M L
R	Allowing submetering and both ex-ante and ex-post baselining will facilitate data access and availability to required baselining data.	L **C** **E** S **M** L	Variability in market practices (e.g. products and services and roles and responsibilities) across different regions or countries due to the absence of universally agreed approaches can hinder the adoption of standardized baselining methodologies.	L C **E** **S** M L
R	Practical insights from demonstration projects enrich the overview of baseline definition methods, enabling stakeholders to understand real-world applications and benefits, which can encourage adoption.	L **C** **E** **S** M L		
T	Appropriate measuring devices implemented for baseline calculation.	L **C** E **S** M L	Lack of standardized data formats and protocols for baselining and settlement can hinder data	L **C** **E** **S** M L

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					exchange and interoperability between different systems and platforms, leading to inefficiencies and errors.						
T	Advances in digital technologies and data analytics enable the development of automated baselining and settlement systems, reducing manual errors and improving accuracy and efficiency.	L	**C**	E	Integrating distinct systems and platforms for baselining and settlement can be technically complex and costly, requiring careful planning and coordination among market participants and technology providers.	L	**C**	E
		S	M	L		**S**	M	L
T	Adoption of interoperability standards and protocols for data exchange and communication can facilitate seamless integration of systems and facilitate the definition of baselines.	L	**C**	**E**	Stochasticity of residential consumption and data availability limitations, can impede the establishment of baselines at the low voltage level.	L	**C**	E
		S	M	L		**S**	M	L

Recommendations:

Baselining methods play a pivotal role for the breakthrough of flexibility markets as they determine how FSPs can be compensated properly. The OneNet project offers an insightful overview of baseline definition methods, enriched with practical insights from demonstration projects to facilitate implementation. A thorough taxonomy of baseline methodologies sheds light on their diverse performance across the critical principles of baselining: simplicity, accuracy, and integrity.

While established services often benefit from well-defined methodologies, emerging markets frequently lack a universally agreed approach, resulting in varied practices across Europe. The emergence of new flexible resources, particularly at the low voltage level, poses challenges in quantifying flexibility due to factors like stochastic residential consumption, data availability limitations, and the disparity in the type of flexible technologies that can be aggregated. Harmonizing procedures across all voltage levels is essential, with a particular emphasis on LV due to its current challenges in baseline methodology and market access for flexibility providers. Nonetheless, best practices for establishing LV flexibility baselines are currently lacking, underscoring the need for further research and standardization in this critical area. In addition, harmonization can potentially be performed at the level of definition of attributes of each method, as well as on the choice of which methods can be viable. Research along these two dimensions is required to identify the level of harmonization or coordination needed, to provide clarity to the FSPs while not limiting their participation die to the absence of baseline methods that can suit their technologies and metering structures.

While no baseline can perfectly embody all three principles of simplicity, accuracy, and integrity due to their inherent nature as estimations, those striking a balance among them can provide a higher level of adequacy depending on the use case considered (e.g. market structure, services considered, technologies considered, aggregation mechanisms permitted, etc.). Consequently, selecting the optimal baseline methodology is a nuanced process, contingent upon a multitude of factors. As different settlement and baselining methods exist, causing inefficiencies and increased costs for FSPs navigating multiple procedures, alignment becomes crucial. Across the demonstrations, some recurrent solutions were identified, particularly concerning baselining methods. However, despite their recurrence, these solutions lack full harmonization due to specifications dependent on factors such as the country of the demo, network topology, digital and infrastructure maturity, and the level of flexibility market implementation. Alignment is essential, which can focus on the definition of attributes within each method rather than solely on the selection of a single method as the latter can constitute a barrier for some technologies, to streamline processes and ensure accurate measurement and settlement of flexibility. While different services may necessitate varying baselining requirements, seeking synergies between markets could mitigate these differences.

The framework developed to assess baseline methodologies highlights that, in practical demonstrations, only a limited subset of available baselining methodologies sees active use. Rather than a broad adoption, the demonstration experience underscores the importance of fostering diverse approaches. Ultimately, the selection of a methodology hinges on several factors: the stakeholders'

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expertise, existing requisites, tool availability, informational resources, regulatory parameters, as well as on the technical characteristics of the service to be delivered, the market mechanisms in place and rules regarding aggregation, and the specification of the diverse set of flexible technologies. In cases where the default option entails a self-declared baseline by the FSP, it becomes imperative to offer alternative solutions should the FSP opt out or fail to submit their baseline. Verification and mitigation measures must also be in place to uphold accuracy and integrity.

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2.8 SO's Needs

KEY MESSAGE:

Gaining insights into flexibility needs and provision is absolutely indispensable to establish flexibility markets. OneNet proposes various forecasting solutions fit to different circumstances to tackle the low visibility and monitoring capabilities in the grid. The roll-out of these solutions is recommended while other measurement solutions are being implemented (smart meter deployment). To properly estimate the impact of flexibility on the network, OneNet also proposes a common network representation between multiple SOs to ensure efficient flexibility procurement. Further alignment between SOs is necessary to agree and align on connection points. Finally, to communicate all insights of grid needs transparently, a traffic light scheme was implemented to inform all stakeholders about possible grid constraints. While sufficiently mature in practice, it is important to continue examining how to properly present this given the heterogeneity in grids.

Solution:

Solution	OneNet Deliverable(s)
TSO flexibility needs evaluation and FSP flexibility provision simulation tool	D3.2, D11.1
F-channel forecasting module	D3.2
Short-circuit levels forecast tool in TSO-DSO substations	
Traffic light scheme	D3.2
A common network representation model covering main network characteristics	D3.2, D7.4

TSO Flexibility Needs Evaluation and FSP flexibility provision simulation Tool

The tool is composed of two modules: one that computes the TSO nodal flexibility needs in the TSO/DSO transformers (EHV/HV) and another that provides the FSPs' optimal dispatch that solves the TSO's flexibility needs. The tool can be used for single or multi-period studies and can run a stochastic analysis. It allows the TSOs to identify the grid flexibility needs profile, taking into consideration different levels of demand uncertainty as input.

F-channel forecasting module

F-channel forecasting module is a forecasting and data analysis tool to forecast weather data and energy production and consumption, for enhancing grid observability and reliability for DSOs and TSOs, and for network planning through providing greater confidence and coordination when making strategic investments. It is

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capable of identifying flexibility resources more precisely and simultaneously for both DSO and TSO grid levels, focusing on the lower voltage levels prosumers, that are usually not covered by detailed energy predictions, in a much more precise manner and over a longer time period than it is being done today.

Short-Circuit levels forecast tool in TSO-DSO substations

The short-circuit current is one of the most important security operational parameters. With the increased penetration of DERs, it is crucial to frequently and periodically monitor it, ideally every 24 hours and with high granularity (e.g., 30 minutes). This OneNet solution computes day-ahead three-phase short-circuit levels for the 63kV bus bars that are the interconnection TSO/DSO transformers (EHV/HV). It uses the grid data and forecasted generation/load profiles known after the wholesale market results. It gives TSOs and DSOs day-ahead short-circuit forecasts in order to improve operation planning activities.

Traffic Light Scheme

OneNet designed a traffic light scheme (TLS) that provides information on grid availability through a User Interface, where users can check if they can activate their flexibility without negatively impacting the grid. As such, the TLS offers crucial information on the availability of the grid to registered flexibility providers to ensure the system is transparent and accessible to all stakeholders. The TLS informs the market that a distribution grid area has constraints in the use of flexibility of the consumers connected to that grid area. This solution allows the FSPs to optimize their portfolio and business case for flexibility provision. In some of the demo implementations the results suggest that the number of FSPs has increased considerably since the commencement of the project and the introduction of the Network Traffic Light system in early 2022. An additional benefit concerns access to a more accurate time schedule of planned grid outages for FSPs.

A Common Network Representation Model Covering Main Network Characteristics

To estimate this impact of flexibility on the network, proper network representation is needed to ensure there are no network violations and to avoid inefficient flexibility procurement. A key challenge here is that flexibility can be sourced from the grid of one system operator (e.g., the DSO) to support the grid of another system operator (e.g., the TSO), thus requiring proper estimation of the impact of flexibility activation by and on other actors. To ensure this, a common network model used by both the DSO and the TSO is proposed by

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OneNet, which ensure a common representation of the network, disclosing topology, network limited, and forecasted baseflows. The conversion of the DSO network representation is done based on a common, open-source data converter format.

Enablers & Barriers:

Table 8. Table of Enablers and Barriers for the above Macro Solution. Topics are grouped into Economic (E), Regulatory (R), and Technical (T) topics.

	Enablers				**Barriers**			
	Topic	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*			**Topic**	**Level of Intervention** *(L - Local, C - Country, E - European) (S – Short, M – Medium, L – Long)*		
E	DSO remuneration mechanism that incentivizes the use of flexibility compared to grid investments is important to benefit from the lower financial and time investments that the OneNet solutions offer (compared to the investments needed with the roll-out of a full metering infrastructure)	**L** **S**	C M	E L	SOs still favor grid investments to resolve their needs which does not incentivize them to forecast flexibility needs properly.	L S	**C** **M**	**E** L
E	Growing flexibility needs require more insights in flexibility.	**L** **S**	**C** **M**	E L	Market recession / energy crisis blocks certain investments.	L **S**	C M	**E** L
R	Local flexibility markets are being encouraged by EU legislation, incentivizing deployment of tools that facilitate flexibility procurement.	L S	**C** **M**	E L	Data sharing between SOs is not (always) allowed, making estimating the impact of flexibility hard.	L **S**	**C** **M**	**E** L
R	National regulators and DSOs are exploring alternatives for complying with the EU Directive mandate.	**L** S	C **M**	E L	Data sharing between market participants is not (always) allowed, making estimating the impact of flexibility hard.	L **S**	**C** **M**	**E** L
T	Trainings and presentations for the users of the new forecasting solutions to explain them how to use new tools.	**L** **S**	C **M**	E L	Heterogeneity in distribution grids makes it hard to standardize tools, blocking their large-scale roll-out.	**L** S	C M	E **L**
T	The possibility of inclusion of DER with less uncertainty about their impact on the grid stability encourages the usage of the forecasting tools.	**L** S	C **M**	E L	Data availability / access blocks further innovation and/or usage of the tools. (In some regions the metering infrastructure is not managed by the grid operator, or data is not readily available in the right format)	L **S**	**C** M	E L
T	Digitalization facilitates forecasting and communication tool deployment and development.	L **S**	**C** **M**	E L		L S	C M	E L

Recommendations:

To establish flexibility markets, being able to identify and signal system operators' flexibility needs is indispensable. Without this, market participants do not know which services they should offer to resolve network problems and grid operators would not know what to order on a market. One key challenge here is that there is a very limited grid visibility in distribution grids today. OneNet steps in by offering more accurate forecasting solutions which help to determine SO flexibility needs more accurately, both in the short- and long-term for both weather and flexibility volumes [1]. It turned out that the forecasts were

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successful in following the real-life production patterns almost completely (D8.2). In addition, OneNet proves that, even in case there are only low levels of smart meter deployment and only 50% LV supervision, no additional LV monitoring is needed with the developed and tested solutions (see for instance Czech demo) (D11.4). In the short run, it is therefore recommended to continue rolling out these solutions to further increase visibility and monitoring in the distribution grid. This is further enabled by the fact that regulation pushes for flexibility markets and that the energy transition has increasing flexibility needs. Nevertheless, it needs to be acknowledged that stakeholders need to become aware of these forecasting solutions, including on how to use them. However, in the medium run, it is important to remove the heterogeneity in monitoring (deployment of smart meters, LV supervisors, sub-metering…) in both LV and MV grids. Not only would this increase scalability and replicability of the OneNet solutions, but it would also be beneficial for baselining and settlement. In addition, the higher the data availability, the more performing the forecasting tools can become. In this regard, barriers to data access need to be removed, as depending on who manages the metering infrastructure, grid operators do not always have access to all required data.

Once it is clear how much flexibility is needed, one needs to ensure that flexibility activations stay within the limits of the grid. To estimate this impact of flexibility on the network, proper network representation is needed to ensure there are no network violations and to avoid inefficient flexibility procurement. A key challenge here is that flexibility can be sourced from the grid of one system operator (e.g., the DSO) to support the grid of another system operator (e.g., the TSO), thus requiring proper estimation of the impact of flexibility activation by and on other actors. To ensure this, a common network model used by both the DSO and the TSO is proposed by OneNet, which ensure a common representation of the network, disclosing topology, network limited, and forecasted baseflows [1]. In order to achieve this, TSOs and DSOs need to agree on connecting points (i.e. the boundary points that define the TSO-DSO border) which calls for a discussion between TSOs and DSOs to clarify and agree upon this, and to see what kind of system will be used to agree, maintain, and exchange such information (D5.4). The key challenge to overcome here are data sharing restrictions between stakeholders. Finally, OneNet proposes a traffic light solution to communicate information on grid availability to the users through a user interface. As such, after having calculated flexibility needs (facilitated through the forecasting solutions and the common network representation model), the state of the distribution grid needs to be signalized (e.g., congestions, voltage profile violation) [14]. OneNet proves that the TLS is mature enough to be implemented in a real environment – therefore the Traffic Light System developed in the project was upgraded with a data privacy and security solution and the whole scheme was integrated into the SCADA systems of all major system operators in the Czech Republic. An important attention point remains the definition of the granularity of the traffic light system to represent the network. The TSO traffic light indicates the status of the whole TSO control area while the DSO traffic light indicates the status of a given network area or element (e.g., a transformer). Also, the DSO breaks down the network issue to network assets (generators and loads) and

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assigns them a sensitivity factor that indicates the degree that the network issue can be resolved by. This implies that the traffic light logic should be applied at asset (or unit) level, thus the physical network can be sufficiently represented (D10.4).

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