one network for Europe

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

D2.2

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About OneNet

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

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

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

OneNet will see the participation of a consortium of over 70 partners. Key partners in the consortium include already mentioned ENTSO-E and E.DSO, Elering, EDP Distribution, RWTH Aachen University, University of Comillas, VITO, European Dynamics, UBITECH Energy, Engineering, and the EUI's Florence School of Regulation (Energy).

The key elements of the project are:

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

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List of Abbreviations and Acronyms

Acronym	Meaning
ACER	European Agency for the Cooperation of Energy Regulators
AEMC	Australian Energy Market Commission
aFRR	Automatic Frequency Restoration Reserves
ASM	Active System Management
BSP	Balancing Service Provider
BUC	Business Use Case
BZ	Bidding zone
CEER	Council of European Energy Regulators
CESA	Continental Europe Synchronous Area
CM	Congestion management
DSO	Distribution system operator
DS	Distribution System
EBGL	European Electricity Balancing Guideline
E.DSO	European Distribution System Operators
ENTSO-E	European Network of Transmission System Operators for Electricity
FCR	Frequency Containment Reserves
FRR	Frequency Restoration Reserves
FSP	Flexibility Service Provider
HV	High Voltage
LFC	Load Frequency Control
mFRR	Manual Frequency Restoration Reserves
MS	Member State
MV	Medium Voltage
LV	Low Voltage
RES	Renewable Energy Sources
RR	Replacement Reserves
SO	System operator
TSO	Transmission System Operator
RES	Renewable Energy Sources
SSNIP	Small but Significant Non-transitory Increase in Prices
WP	Work Package

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Executive Summary

The changes in the energy landscape, accompanied by the changes in regulation, call for a new, harmonised approach to system services and products. The focus of Task 2.2 lies in the analysis of existing services and products and the development of new, standard products. The analysis of these system services is one of the objectives of this deliverable. Moreover, the currently existing products should be re-evaluated to ensure not only that they are still fit for purpose but also that they facilitate access to all the relevant sources of flexibility. Otherwise, there is a risk that the network does not operate efficiently as it excludes parts of the sources of flexibility.

To reach the objectives of Task 2.2, this deliverable elaborates a theoretical framework for products building on the discussions on systems services and products developed in previous research and innovation projects. The product framework poses three main questions that need to be considered in the identification of the products: (i) what the SO is going to use the product for, (ii) what the relevant attributes for the product are, and (iii) what the values of the different attributes are.

To be able to answer consistently the first question, this task developed a definition of the different systems services that SOs face. To define these system services, we identified a number of drivers such as the need they are aiming to address (e.g. congestion management or voltage control) or the timeframe of the service (e.g. operational, short term or long term). These drivers will be the base for the definition of a product as they will help to classify the system services that the SO would aim to obtain from a product as well as facilitate the transformation of these system needs into well-defined products (i.e. what are the relevant attributes for the products).

Using that framework, we developed a number of harmonised products that address the need for common system services exploiting all network resources, which are then mapped against the different services and products demonstrated in the OneNet clusters of demonstrator partners. Harmonised products are products where there is some degree of convergence but at the same time still margin for differentiation between the products. Under this definition, standard products are just one extreme option inside of a spectrum of potential levels of harmonisation (i.e. standardised products are fully harmonised products). To identify the level of potential harmonisation, expected benefits need to be compared with the costs to surpass any harmonisation barrier. In those cases where the benefits surpass the costs, it would be advisable to increase the harmonisation between products.

Through framework analysis, we found that products can be split up into two main groups. The first group is the frequency control products group. These products have a larger margin for harmonisation as potentially larger benefits could be achieved by harmonising between bidding zones as they do not require locational

information. Furthermore, TSOs have a good understanding of these products as they have been using them for a while which reduces the costs of harmonisation. Our approach is consistent with the current where frequency control products are being harmonised by the TSOs through a number of projects (e.g. PICASSO[1], MARI[2], TERRE[3]). As these efforts are already ongoing, we based our own harmonised products on those being developed in these projects.

The second group of products is the non-frequency control products group. The need for harmonisation in these products is smaller as they are location-specific, meaning that the main rationale for harmonisation would be to facilitate the interactions between TSO-DSO-consumers by reducing the diversity between products. Furthermore, the potential barriers to harmonisation could also be higher as DSOs have only recently started using / considering some of these products and this could result in harmonised products that do not work for some of the SOs. For this second group of products, an approach with a certain degree of harmonisation was developed to facilitate the coordination between TSO-DSO-customers without attaining full harmonisation. A list of attributes was identified that would allow an FSP to understand whether they can deliver the product, but at the same time allowing a certain degree of variety among the values for some of the product attributes.

In the next step, the developed standard products were compared with the products being proposed by the OneNet demonstrators. We found that, among the demonstrator partners, there is a focus on the non-frequency control products, where there is currently less practical experience.

These harmonised products were also compared against the products that TSOs and DSOs (inside of the project as well as outside) had identified as potential future products. This comparison shows that the harmonised products included all the relevant products identified by the different SOs. Furthermore, as part of that analysis it also became clear that both TSOs and DSOs are considering similar non-frequency products. Therefore, there would appear that consistency between the definition of these products could also facilitate the TSO-DSO coordination as well as the operations of the FSPs as they would only need to identify one set of products instead of separate products for TSOs and DSOs.

Finally, in this project we also considered the potential evolution of product design. We identified two extreme evolutions. The first extreme is the supermarket approach where SOs would have the full responsibility to identify the best FSP for their needs at each point in time and the second extreme is the superproduct where FSPs should provide one product that the SO can use to address all its needs. Even if those two extreme approaches are unlikely to arise, potential hybrid options were identified that could facilitate the integration of all different sources of flexibility into the management of the energy systems.

To conduct the analyses described above, different methodologies were used. To be more specific, we used information coming from previous projects and policy initiatives included in the analysis carried out within Task 2.1, we conducted broader desktop research to consider relevant academic literature, multiple questionnaires

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were sent to the TSOs and DSOs both inside and outside of the project as well as to the members of the demonstrators to identify the services and products they are planning to test. These questionnaires were developed together with Task 3.1 and aimed to support the identification of the main services and products that will be tested in OneNet. Finally, we conducted workshops with the members of WP2 as well as the different demonstrators' clusters aimed at exchanging information between the different parts of the project.

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1 Introduction to Task 2.2

The European 2030 Climate and Energy Policy Framework, endorsed by the European Council, set a target of at least 40% domestic reduction in greenhouse gas emissions by 2030 compared to 1990 and an EU target of at least 32% for the share of renewable energy in the final energy consumption in the EU in 2030, binding at EU level [4–6]. The latter translates into electricity consumption originating from at least 50% Renewable Energy Sources (RES) [4,7]. Moreover, this new energy scenario will be mostly based on distributed energy generation. The increase in RES and distributed energy sources has as a consequence that electricity supply will become more complex because of the significant impact of RES, such as wind and solar, and distributed generation on the planning and operation of the power grids (both transmission as well as distribution grids) [7,8]. These changes create challenges that were not previously present in the pan-European electricity system.

A first challenge faced by TSOs and DSOs alike lies in the fact the increased reliance on RES and distributed energy require changes in the way they operate their grids. DSOs will have to connect large amounts of renewable generation to their networks. To do this, DSOs cannot rely anymore only on their traditional toolkits such as network reinforcement and direct load control but they will need to bring in new tools such as flexibility and (local) market-based approaches [9]. Equally, TSOs will also need to expand their toolkit to make better use of new sources of flexibility that will allow them, for example, to deal with a growing need for balancing services to maintain the frequency in the grid resulting from the use of new energy sources where the output is more difficult to forecast.

These new and changing roles go hand in hand with challenges brought about by recent changes in regulation. The Electricity Directive of the Clean Energy Package [7, Art. 32, §1] states that 'DSOs shall procure flexibility services in accordance with transparent, non-discriminatory and market-based procedures unless the regulatory authorities have established that the procurement of such services is not economically efficient or that such procurement would lead to severe market distortions or higher congestion'. The fact that DSOs are now allowed to procure flexibility also implies that there will be a need for and development of new DSO services. Concerning TSOs and market-based solutions, the Electricity Directive of the Clean Energy Package [7, Art. 40, §4] states that 'TSOs shall procure balancing services subject to transparent, non-discriminatory and market-based procedures. This applies as well to the provision of non-frequency ancillary services [1] unless 'the regulatory authority has assessed that the market-based provision of non-frequency ancillary services is

[1] The Active System Management report [15] defines ancillary services as services provided to DSOs and TSOs to keep the operation of the grid within acceptable limits for security of supply and are delivered mainly by third parties (i.e. control power for frequency control, reactive power for voltage control, black-start capabilities) or by the TSOs and DSOs themselves (topology changes and integrated network components). Ancillary services are classified as a) frequency ancillary services (mainly for balancing); b) services for congestion management; and c) non-frequency ancillary services such as voltage control. It is important to notice the difference in definitions with the Electricity Directive [7] where a distinction is made between services provided to DSOs (i.e., 'flexibility services') and services provided to TSOs (i.e., 'ancillary services').

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economically not efficient and has granted a derogation' [7, Art. 40, §5]. Moreover, the European Electricity Balancing Guideline (EBGL) [10] requires the harmonisation of certain balancing market processes and rules. Therefore, TSOs and other relevant stakeholders are in the process of establishing pan-European balancing platforms [11–14]. These integrated market platforms require the use of standardised and harmonised products.

Finally, as both DSOs and TSOs will have to overcome obstacles because of the changing energy landscape, they will need to pay more attention to coordinating with each other as well as with FSPs[9]. As mentioned above, TSOs and DSOs are now both required to procure flexibility services through market-based procedures. These flexibility services can also be provided by distributed sources owned by FSPs. Therefore, distributed sources must have the same opportunities as transmission-connected sources to increase their value and revenue by participating in balancing and congestion management in the transmission grid (next to participating in the distribution-related markets). Hence, proper coordination mechanisms need to be agreed upon between TSOs and DSOs [15] that do not affect their interactions with FSPs. These coordination mechanisms will of course also have an impact on the design of products and services.

The changes in the energy landscape, accompanied by the changes in regulation, call for a new, harmonised approach to system services and products. The focus of Task 2.2 lies in the analysis of existing services and products and the development of new, harmonised products. The analysis of these system services is one of the objectives of this deliverable. Moreover, the currently existing products should be re-evaluated to ensure they are still fit for purpose but also to ensure that they facilitate access to all the relevant sources of flexibility. Otherwise, there is a high risk that the network does not operate efficiently as it excludes parts of the sources of flexibility.

1.1 WP2 objectives

Work Package 2 (WP2) in OneNet is titled "Products and services definition in support of OneNet". The main objective of this WP is to set the basis of the work to be done in the OneNet project. It looks back to the market solutions and digital platforms presented so far in the EU pilot projects, revisits European policy frameworks, summarizes their contributions and benefits and builds on this information to sketch the new products and business use cases (BUCs) proposed in the OneNet Project. These products and BUCs will strongly engage the consumers to maximize the flexibility resources that the grid operators can use to meet the clean energy challenges. The differences among EU markets will be reviewed and specific priorities for KPIs, Scalability and Replicability of OneNet solutions will be devised to enable the pan-EU integration of these new services and products digitally procured for system operation.

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1.2 Description of Task 2.2

Within WP2, Task 2.2 elaborates a theoretical framework for system service product based on the different services and products being proposed in the various research and innovation activities (Deliverable 2.1) and the models defined in the Active System Management (ASM) report [15]. This results in a set of harmonised products[2] for OneNet addressing the need for common system services exploiting all network resources. In a second step, the task maps the different services and products demonstrated in the OneNet clusters against the standardised products. The outcome of this task is an input to Task 2.3 with the objective to avoid locking flexibility on the BUCs. Third, the task assesses the gap between the existing set of services and the final goal of having a common EU-wide harmonised product framework. Different barriers and attention points on the one hand, and possible tracks for innovation on the other will be analysed and proposed.

When considering these issues, this task needs to consider the interactions with the other areas in the OneNet project. The main interactions are summarised in the figure below:

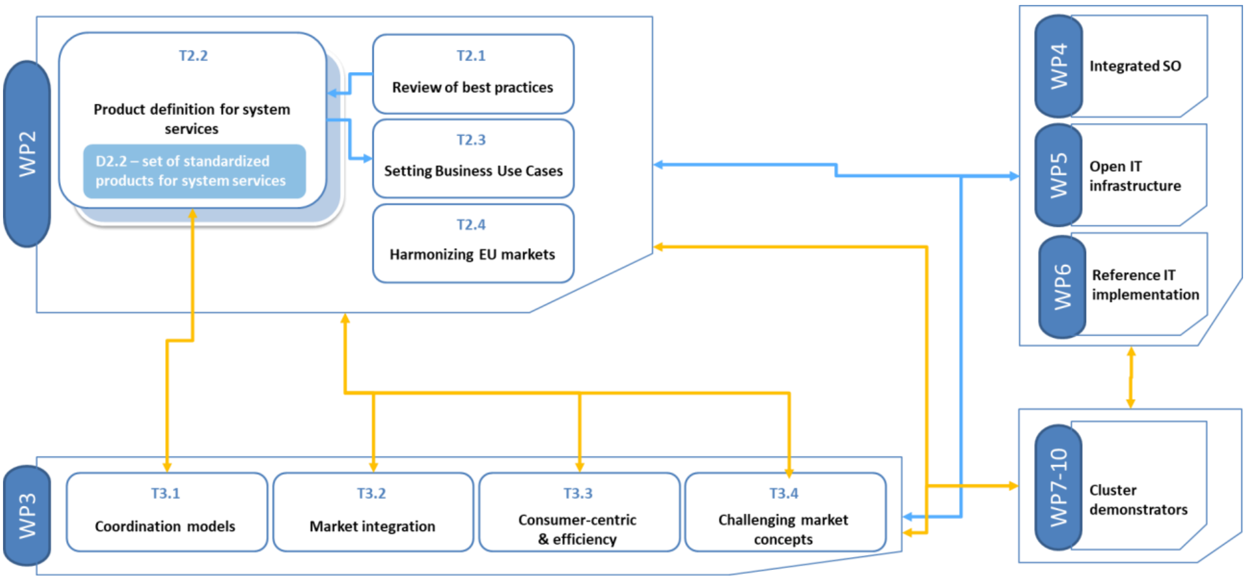

Figure 1-1 Interactions between Task 2.2 and other work packages in OneNet

Figure 1-1 shows the strong interconnection between all work packages being taken in OneNet. As indicated above, Task 2.2 builds on the findings in Deliverable 2.1 (developed in Task 2.1) as we use this input as one of the main starting points of our analysis. Furthermore, Task 2.2 has also worked in close coordination with Task 3.1 which is considering the potential approaches TSOs and DSOs could use when acquiring the products

[2] The difference between a harmonised and standardised products is discussed in Section 5.1.

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identified in this report. These two tasks run in parallel and their output should be consistent. To achieve this we have share resources as well as having coordination sessions when it was required.

Task 2.2 constitute an important input into Task 2.3. Task 2.3 will aim to analyse the BUCs being put forward by the different demonstrators. Therefore, the matching of the harmonised products against those put forward by the different demonstrator partners that being undertaken in Task 2.2 will provide direct input into the work in Task 2.3. Furthermore, by developing a framework for the development of system service products, Task 2.2 also provides both the different demonstrators and Task 2.3 with a reference framework to be used in the development and evaluation of the BUCs.

Finally, the work from Task 2.2 will also be considered within the definition of requirements and development of IT solutions in WP 4, 5 and 6.

1.3 Structure of the deliverable

Figure 1-2 presents the structure of Deliverable 2.2.

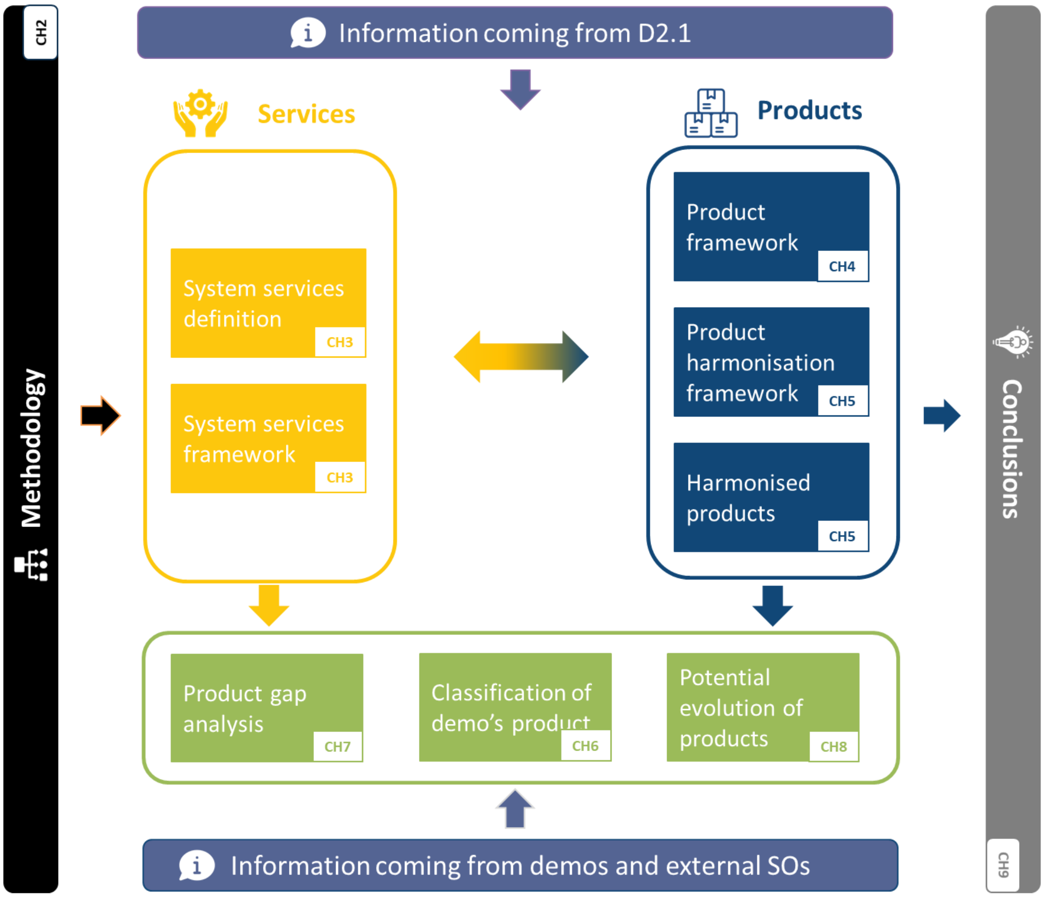

Figure 1-2 Structure of Deliverable 2.2

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This deliverable focuses on services and products. First, Chapter 3 defines systems services and subsequently develops a framework for these services. In a similar way, the subsequent Chapters 4 and 5 focus on products for these system services where Chapter 4 develops a generic product framework and Chapter 5 elaborates on a product harmonisation framework. Moreover, the same chapter then proposes a number of harmonised products. Chapters 3 to 5 are developed based on information collected from OneNet Deliverable 2.1 and own insights gained during Task 2.2.

Next, the theoretical approach of Chapters 3 to 5 is followed by the implementation of the frameworks onto the products used by the demonstrator partners (Chapter 6). Then, based on the classification of the demonstrator partners' products (Chapter 6) and the theoretical knowledge gained on products and services (Chapters 3 to 5), a gap analysis concerning products is conducted in Chapter 7. A final chapter provides insights into the potential evolution of products (Chapter 8). Chapters 6 to 8 are developed based on the knowledge gained from the theoretical work on products and services and based on the inputs provided by the demonstrator partners and SOs external to the project.

There are two overarching chapters in this deliverable. The overall methodology is described in Chapter 2, where, for each content chapter (i.e., Chapters 3 to 8), a separate section explains the methodology behind that respective chapter. Finally, the work of Task 2.2 is concluded in Chapter 9.

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2 Methodology

The core objective of this deliverable is, as indicated by its title, to develop a set of harmonised products for system services in the TSO-DSO-consumer value chain. To develop these products, we have used systematic approaches for the identification and definition of services and harmonised products. As shown in Figure 1-2 above, the result of those systematic approaches has been the identification of a set of services and harmonised products that have been used to consider potential gaps in the products that SOs are considering going forward as well as classifying the products that the different demonstrators in this project are planning to consider.

To undertake that analysis, we used a multidisciplinary team that considered the questions presented in the figure below. This figure also links those questions with the chapter in the report.

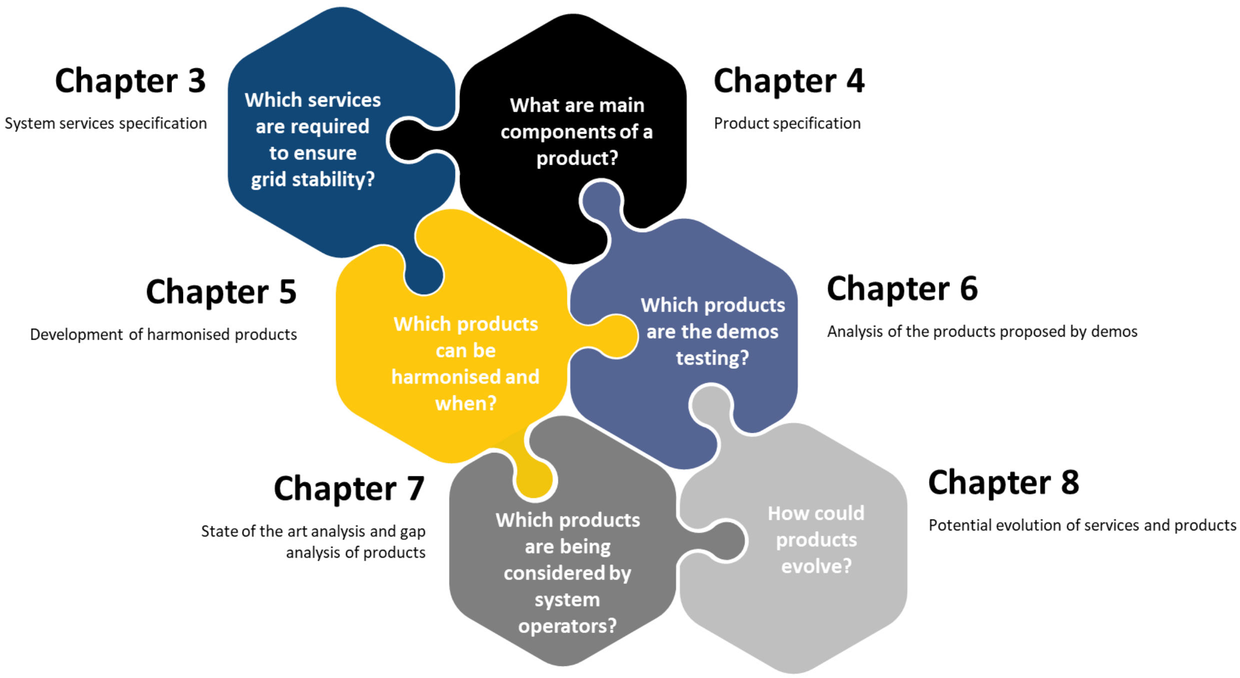

Figure 2-1 Main questions to be addressed in this deliverable

To answer these questions, the team has aimed to have a high level of interactions with the broad OneNet consortium to ensure that we obtain a wide view of the sector. This engagement has also aimed to facilitate the development of a common approach among all different parts of this project.

To inform our analysis, the following sources of information were used:

- Information coming from previous projects and policy initiatives included in the analysis carried out within Task 2.1. This information included the main characteristics of the services and products that were developed in these projects.
- Broader desktop research to consider relevant academic literature.

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- Questionnaires to the TSOs and DSOs both inside and outside of the project. The focus of these questionnaires was the services and products SOs have currently in use as well as those they have identified as necessary going forward (see Sections 11.3 and 11.4 in Appendix).
- Questionnaires to the members of the demonstrators to identify the services and products they are planning to test. These questionnaires were developed together with task 3.1 and aimed to support the identification of the main services and products that will be tested in OneNet (see Section 11.5 in Appendix).
- Workshops with the members of WP2 as well as the different demonstrators' clusters. These workshops aimed at exchanging information between the different parts of the project. From the perspective of Task 2.2 these workshops were used to obtain initial feedback on the ongoing work and facilitate the dissemination of our analysis into the work of the demonstrators as well as collecting information about the products and services that the different demonstrators are planning to test in this project.

The precise use for each one of these sources of information is presented in the following sections when the methodology adopted for each one of the sections of this report is discussed.

2.1 Methodology for the specification of system services

To answer the question, "what are the service required to ensure the stability of the grid?" this report builds on the relevant definitions set in EU directors as well as the information collected in Deliverable 2.1 of OneNet [16]. In that deliverable, we found different definitions that were used in previous H2020 projects of what constitute system services. This, together with the experience of the different members of the team allowed us to obtain the definition we have used in this report.

Furthermore, in that deliverable, we also identified the definitions of the needs and the services that were considered in previous H2020 projects. We used that information as a starting point for the development of our service framework. This framework provides the list of drivers that we have used in the definition of the services that SOs need as well as a definition of these services.

With that framework, we were able to identify the relevant system services faced by the SO. To refine both our framework and the definitions of our system services, we run a OneNet-wide workshop where we presented our initial findings and obtained feedback from the remaining members of the project.

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2.2 Methodology for the product specification

Our first step in the development of standard products was to understand the main components of a product. These components resulted in a framework that allows us to define a product in detail. As for the development of the system services, the first step in the development of this framework was to consider the information collected in Deliverable 2.1 [16]. This input was also expanded to include a broader literature review that included, among other documents, the Active System Management Report [15].

With this information, we developed a product framework that goes a step further than just a list of attributes. In our framework, the first component of a product is its definition, i.e. the objectives it aims to achieve. It is only then that it will be possible to identify the relevance of each one of the product attributes we have identified based on the work in Deliverable 2.1 [16] and our literature review. In addition, our framework goes a step further by identifying the roles different actors play in the definition of the products.

As with the system service framework, this product framework was refined in conversations with a broader audience inside of the project via organised workshops.

2.3 Methodology for the development of harmonised products

The development of our harmonised products for the TSO-DSO-client value chain is based on three pillars. The first one of these pillars is the product framework described in the previous section.

The second pillar was a literature review that allows us to identify the potential for standardisation of the products used in the delivery of system services. This literature review constitutes the base of our approach to standardisation (which in this report is often described as harmonisation as that is identified as a less restrictive definition) as it helps us identify the advantages and potential barriers to standardisation.

The last pillar for the development of our product was the input obtained from TSOs, DSOs (both inside and outside of the OneNet project) and, as far as possible, providers of flexibility. This feedback was obtained using a combination of questionnaires, workshops, and individual conversations with the different agents. This information allowed us to identify the main products each agent is identifying and their characteristics.

With the information coming from those three pillars, we developed a process to identify the relevant harmonised product from the point of view of SOs and providers of flexibility.

2.4 Methodology for the classification of demonstrator partners' products

The objective of this analysis was to ensure the alignment between the products developed by the demonstrator partners and the framework presented in this deliverable. . Furthermore, as part of this

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engagement, demonstrator partners were asked to consider potential innovations on the products and services they want to test.

The information for this analysis was the result of a recurrent engagement with the demonstrator partners. This started with the circulation of a questionnaire (jointly defined with Task 3.1) to identify the services and products each demonstrator partner was considering. Based on this information and a follow-up workshop with each cluster demo, we created a live document that allowed a progressive refinement of the definitions of the services and products that each demonstrator partner is aiming to test as part of OneNet.

The results of that life document, together with harmonised products presented in this deliverable constituted the base of this chapter. Our initial classification of the products was discussed with the different clusters as part of one of our workshops. One thing that we should note is that, given the early stages of the project, these services and products may keep evolving as additional work is being undertaken within the different demonstrator partners.[3]

2.5 Methodology to undertake the analysis of the gap analysis on products

One of the objectives of this deliverable was to undertake a gap analysis of the different products that are or are being considered by SOs.

To undertake this analysis, two questionnaires were circulated to DSOs and TSOs (including both OneNet partners and other DSOs and TSOs). These questionnaires (available in Chapter 11) aimed to identify the products that these SOs use or are planning to use going forward to manage their networks. To simplify the analysis, the frequency management products that are being standardised in programs such as Regelleistung, PICASSO, MARI or TERRE [11–14] were excluded as we understand that those products will be implemented across most jurisdictions in the European Union.

The responses to those questionnaires were combined, together with the information received from the demonstrators in this project to identify whether those products were consistent with the harmonised products developed in this document. This analysis was undertaken separately for TSOs and DSOs to identify potential differences between their needs. The separate analysis was then combined to identify those products that will be required by both TSOs and DSOs.

[3] The final services and products tested in the demonstration may differ from those described in this document, and in extreme situations may not be presented at all.

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2.6 Methodology to evaluate potential evolutions of services and products

This section analyses the potential evolutions of the products definition and what it could mean for the associated markets. It builds and expands on the work presented in EU-SysFlex [17] where potential expansions in the definitions of the products were considered.

To expand on this work, we undertook a desktop review of the literature in this area as well as developing an original analysis based on the expertise of the members of the team. This analysis was then expanded with the comments of the broader OneNet team that were obtained as a result of a workshop with the members of the different clusters as well as engagement with external parties (NODES) with experience in this area.

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3 System Service specifications

This section presents the system services that have been identified in our analysis. We start by proposing a common definition of system services which then constitutes the base for the framework we have used to identify the system services proposed in this deliverable. In this section we have identified the system services faced by both TSOs and DSOs. When appropriate we have indicated whether some of the services have more / less relevance for some of the SOs.

3.1 Definition of system services

SOs have the responsibility of operating their networks securely and reliably. When operating their networks, they will face a number of system needs which can be defined as "requirement of a high-level strategical action or set of actions for the better operation and/or planning of the grid (in terms of security and quality of supply) related to a specific grid aspect. In this sense, as will be shown later, congestion management has, for example, been considered a system need" [15, p. 29].

To address their system needs, SOs require several system services. As indicated in Deliverable 2.1 [16], a system service will be defined in this project as the action (generally undertaken by the network operator) which is needed to mitigate a technical scarcity or scarcities that otherwise would undermine network operation and may create stability risks.

Even when all network operators face similar system needs, the relevance of different system needs can vary between distribution or transmission networks since these networks serve different purposes. For example, Article 2 in the EBGL [10] sets that TSOs are responsible for undertaking actions to "ensure, in a continuous way, the maintenance of system frequency within a predefined stability range […] and compliance with the amount reserves needed concerning the required quality". Therefore, the needs that arise as a result of the obligation to keep the balancing of the grid, will only be addressed by TSOs.

3.2 Framework for the evaluation of system services

With the definition of system services in hand, this section presents the framework we have used to identify the system services as well as a detailed definition of the services we are proposing.

When identifying system services, it is important to consider the level of granularity that is required in each case. High-level classification of system services results in definitions that cover a large range of system needs. This approach would be advisable when those high-level definitions are sufficient to deliver the objectives of the project. For example, a project that focuses on the development of a fully new source of flexibility, could use a high-level definition of services (e.g. congestion management services) when considering what needs could

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be addressed by that new source once the objective is the development of new technology instead of a detailed analysis of all its potential uses.

In projects where the focus is on how needs are addressed, as is the case in OneNet, more detailed classifications of system services could be required. To increase the level of detail in these system services, we have identified the drivers that cause the differences between services. For this framework we have used three main classification drivers:

- Division by system needs / scarcity – This is the most common classification of system services used in the industry. Furthermore, our definition of system services identifies this as the main characteristic of these services.
- Division in the function of timing when the system need is addressed – This driver is relevant as it affects the tools that the SO could use to address the system need. For simplicity, we have grouped this timing into three categories:
    - Long term planning (over one month);
    - Short term (between one day and one month);
    - Operational (intraday or near real-time).
- Division in function of the reason causing this need – this is important as it will affect the way that the needs can be addressed. We have grouped this into two categories:
    - Corrective – these are needs that arise as the result of unexpected circumstances (e.g. due to unexpected problems in the grid or unexpected drop on the energy being fed-in by a generator);
    - Predictive – these needs arise as the result of forecast circumstances. These needs could arise both in the short and the long term:
        - short-term – these needs would be predicted days or hours ahead of the actual delivery of the energy. They could be caused by, for example, planned outages (e.g. due to maintenance works) or improved weather forecasts showing a change in the availability of some DER;
        - long-term – these needs could be predicted months/years ahead. These needs could arise as a result of the regular planning process to ensure the grid remains secure under forecasted organic growth.

Also, for some of the services the framework in this report considers other drivers that are particularly relevant for some of the system needs:

- Frequency control operational system services are divided with respect to the amount of time that the SO has to address the system need, which can range from real-time to hours ahead of the actual

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consumption of energy. We use this driver as it is the one that has been used in the harmonisation of the products used for these services.

- Voltage control system services are divided depending on whether the SO uses active or reactive power. Traditionally, most voltage control needs were covered by reactive energy. However, in recent years, operators have been considering the possibility of the use of active energy for these services. Therefore, we consider it was appropriate to reflect this new reality in our service definition.

Based on these drivers, the diagram below shows the classification of system services mapped by the different needs that the SOs have and by timeframe (green cells are not considered as services in this report but they are included to ensure the completeness of the table).

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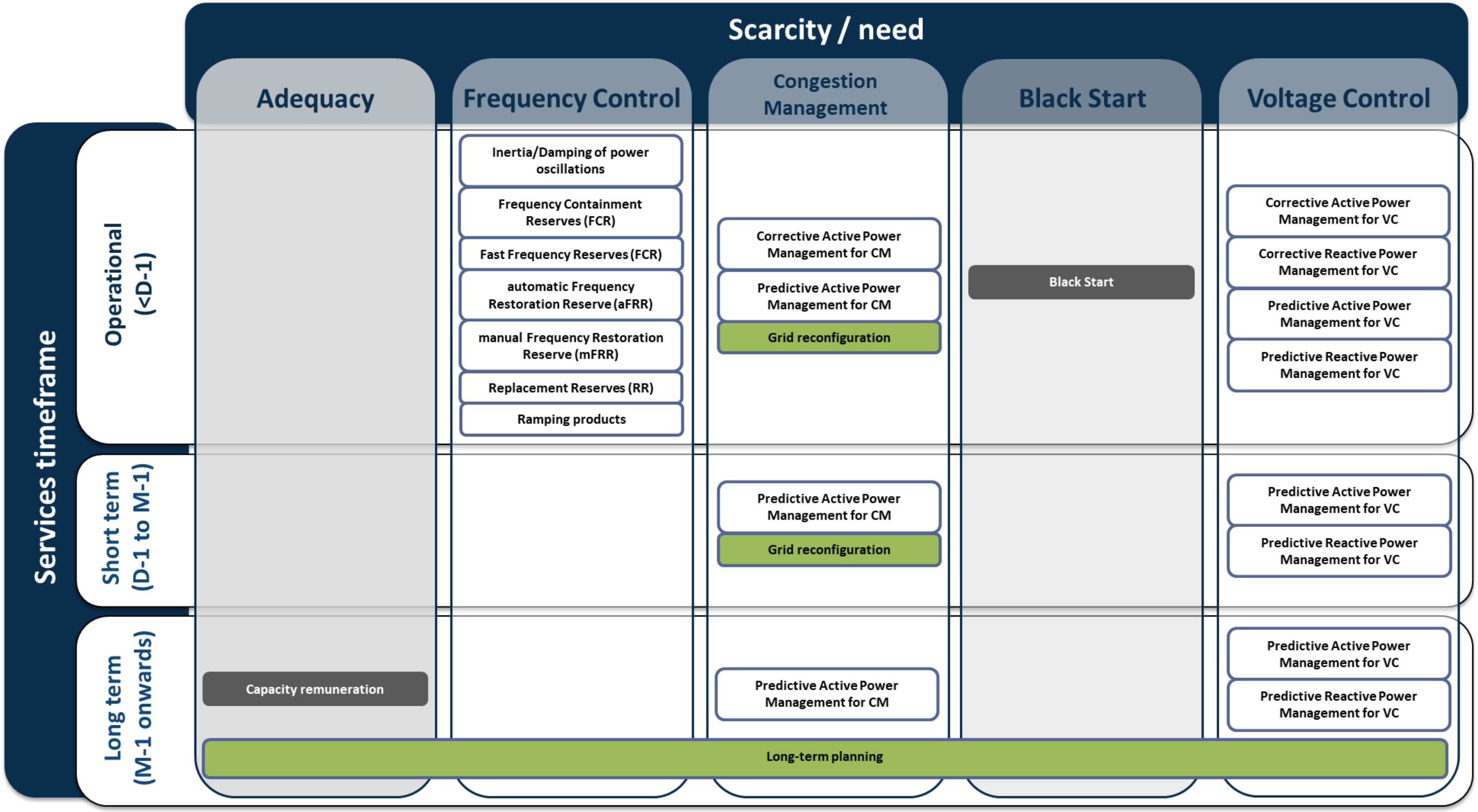

Figure 3-1 - System services identified in OneNet

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As shown in the figure, the needs can be grouped into five large categories: adequacy,[4] frequency control, congestion management, black start and voltage control. In our analysis, we have put special emphasis on three of these needs: frequency control, congestion management and voltage control. These are the three needs that arise more often in the operations of the SOs and they are the focus of most of the demonstrators in this project. For each of these needs, more granular descriptions are presented in the sections below.

3.2.1 Frequency Control

This is a need that concerns TSOs that have to ensure that the system frequency remains within a predefined stability range. Typically, when generation and demand are balanced, the frequency remains constant (usually at 50 Hz) and all synchronous machines rotate at the same speed. Any imbalance between generation and demand, e.g. following a severe system event, will cause a deviation of frequency from the nominal. To mitigate this need, SOs resort to "balancing" services that can be defined as all actions and processes, on all timelines, through which TSOs ensure, in a continuous way, the maintenance of system frequency within a predefined stability range [7, Art. 2]. Although all frequency control services in our framework fall within the Operational timeframe, they have some differences between each other as can be seen in the following table.

Table 3-1 Services for Frequency Control needs

Service	**Definition (based on** [19]**)**
Inertia / Damping of power system oscillations	Service that allows the reduction of power system oscillations. Damping of power system oscillations is one of the main concerns in the power system operation mainly dealing with the angle stability of power systems. These oscillations, when not well damped, may keep growing until loss of synchronism. These low-frequency oscillations affect the stability and efficiency of the power system.
Frequency Containment Reserves (FCR)	Frequency containment is an automatic function that aims at stabilizing the frequency at a steady-state value within the permissible maximum steady-state frequency deviation after disturbances in the high-voltage grid. By the joint action of all automatic devices, the process ensures operational reliability in the synchronous area.
Fast frequency reserves (FFR)	Fast Frequency Response is defined as any type of rapid active power increase or decreases by generation or load, in a timeframe of less than 2 seconds, to correct supply-demand imbalances and assist with managing frequency.
automatic Frequency Restoration Reserve (aFRR)	This service is a centralised automatic function intended to replace FCR and restore the frequency to the target frequency – usually 50.00Hz. In contrast to mFRR (see below), aFRR 'can be activated by an automatic control

[4] Sometimes adequacy is distinguished from firmness. Adequacy is used for long term where capacity investments are considered, while firmness is that enough firm capacity is available for example for the day ahead, see for example "Regulation of the power sector, Ed. Ignacio Pérez-Arriaga"

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Service	Definition (based on [19])
	device'. This control device shall be an automatic control device designed to reduce the Frequency Restoration Control Error (FRCE) to zero.
manual Frequency Restoration Reserve (mFRR)	Manual Frequency Restoration is a manual change in the operation set-points of the reserve (mainly by re-scheduling), to restore system frequency to the set point value frequency and, for a synchronous area consisting of more than one load-frequency control area, to restore power balance to the scheduled value.
Replacement reserves (RR)	The reserve replacement process replaces the activated FRR and/or complements the FRR activation by activation of RR. The replacement reserve process is activated in the disturbed Load Frequency Control (LFC) area. Activation is semi-automatic or manual.
Ramp control	Ramp control or ramping margin is a service that is intended to ensure system stability by responding to changes in the supply and demand of energy. Its timeframe is longer than a traditional FRR reserves - up to 8-hour ramping period with 8 hours of maintaining level of production.

3.2.2 Congestion Management

This need arises when the power flows performed by the SOs violate the thermal limits of at least one network elements (e.g. by exceeding the power capacity of an asset). Congestion Management could affect both distribution and transmission networks.

In this deliverable, we divide these services further by considering the reasons that cause these needs to arise.

Table 3-2 Services for Congestion Management needs

Service	Definition
Corrective active power for Congestion Management	For targeting congestion management needs caused by network failures and subsequent corrective actions (e.g. switching state changes, ad-hoc active power intervention), through the activation of active power generation and demand side sources. Given that these services are caused by unexpected situation, they could only arise in our operational time frame. This service needs products with fast activation and their duration should be aligned with the thermal limits of the congested assets.
Predictive active power Congestion Management	Predictive active power management is a service meant to solve congestions that are forecastable (e.g. congestion arising due to forecast maintenance activities or long-term planning process). These needs could arise in all three times frames considered in our framework. However, the reasons behind these needs could be different which could result in different products to address them. For example, at the operational level, the SO could forecast congestion as a result of a change in the weather forecasts affecting the availability of some FSPs while in the long-term time-frame, this service can be considered either as a complement or even an alternative to traditional grid investments.

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3.2.3 Voltage Control

One of the main parameters to determine the quality of the electricity supplied by SO' networks is the Voltage magnitude. There are two kinds of problems related to voltage control, the undervoltage which means that the voltage level is below the lower acceptable limit and the overvoltage when the voltage level exceeds the upper acceptable limit. Voltage control services arise when the SO faces situations when the SO's network is not within these acceptable limits. As with the congestion management services, these services can also be further divided depending on the reasons behind this need to arise. Furthermore, as discussed above, in the case of voltage control, we have also divided these services depending on whether they are addressed using reactive and active power as you can see in the following table.

Table 3-3 Services for Voltage Control needs

Service	Definition
Corrective active power management for Voltage Control	For targeting voltage control needs caused by network failures and subsequent corrective actions, through the activation of active power sources. In the case of activation, active energy is increased/decreased. This service can be used to address local voltage problems in the MV and LV grids and should be available for fast activation.
Corrective reactive power management for Voltage Control	For targeting voltage control needs caused by network failures and subsequent corrective actions, through the activation of close to real-time reactive power sources. Reactive power consumption, or injection, can be used to reduce, or increase, the voltage in the HV, MV and LV grids. This service needs to be available for fast activation, which duration is heavily dependent on the grid's voltage level (HV, MV).
Predictive active power management for Voltage Control	Predictive active power management is meant to tackle needs that are forecastable through the reservation and possible activation of active power resources. This service can be used to address local voltage problems in the MV and LV grids.
Predictive reactive power management for Voltage Control	For tackling forecastable reactive power needs to solve voltage problems, in the HV, MV and LV grids. This service aims at acquiring resources, in the short-term, capable of injecting or absorbing reactive power for predictable grid voltage fluctuations scenarios.

3.2.4 Other system needs

As discussed above, system services also face other needs when managing their networks. The two main groups of needs that have not been considered in detail in this deliverable are:

- Adequacy – refers to the need to ensure that exists of sufficient capacity to meet system demand and to tackle that, the SOs should find an optimized equilibrium between generation and demand.
- Black Start – it is the need that arises when the SO has to restore the service to a local microgrid and support the main system reconnection after a blackout.

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The literature has also identified other services for SOs such as Support to Islanding and Support in Extreme Events needs, as referenced in [20]. We understand that these services are not a service in their own right but they are the combination of needs that could arise under certain circumstances but that they are already included in the services discussed above. Support to island and Extreme events needs can be understood as a complex service made of basic services such as local frequency control and/or, local voltage control.

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4 Product specifications

This chapter develops a framework for the definition of products that could be used for the delivery of the system services. When developing this framework, we do not only consider the position of the SOs but also of the FSP. As a result, the analysis in this section extends previous discussions on coordination between TSOs and DSOs to include also the perspective of the service providers, the FSPs (including aggregators and more broadly investors in new sources of flexibility). This will help us to provide a broader perspective of the challenges faced when developing system products and the incentives they provide to the different operators in this market. This framework will then constitute the base for the development of harmonised products in the following chapter of this document.

As discussed in Deliverable 2.1 [16], and building on the definition of products developed in previous Horizon 2020 projects, a product is here defined as a tradable unit that the network operator acquires from the flexibility providers and that entails the option to deliver a service in case of activation (this activation can be automatic). The technical requirements of the scarcity mitigated by the relevant service and the characteristics of all potential flexibility providers will determine the attributes of the tradable unit.

By focusing on tradable units, that definition focuses on the need for those products to be procured using a market mechanism. As a result, this excludes from the potential list of products those measures such that, even if they could satisfy similar needs, would not be tradable under a market mechanism. This includes, for example, mandatory curtailment (i.e. not based on a tradeable unit), (non-tradeable) redispatch, network reinforcements, mandatory delivery of flexibility or changes in flows in the network.

To develop the product framework, this section starts by identifying the attributes or characteristics that could be relevant when defining products (Section 4.1). Section 4.2 then uses those attributes as the base for the framework of our products. This framework starts with a description of the product being considered and then it identifies the decision/actions that the SO/MO as well as the FSP need to consider when describing this product.

4.1 Product attributes

To describe each one of the products, their main attributes must be identified. After considering the experience in other projects, as well as those attributes from the ASM report [15], the table below presents the main attributes selected and their definitions:

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Table 4-1 List and definitions of product attributes

Attribute	Definitions	Source
Capacity / energy	This attribute determines whether the product accounts for the possible acquisition of capacity (in MW) or energy (in MWh)	OneNet
Active / reactive power	Type of power that will be acquired by the SO	OneNet
Location information included	This attribute determines whether certain locational information needs to be included in the bid (e.g. identification of Load Frequency Control (LFC) area, congested area...)	[21]
Certificate of origin	This attribute determines whether the FSP would be required to deliver a certificate of origin of the energy they sell.	OneNet
Level of availability	When there is uncertainty about the capacity of an FSP, this attribute would determine the percentage of time or the committed flexibility that the FSP would be able to deliver the product.	OneNet
Symmetric / asymmetric product	This attribute determines whether only symmetric products or also asymmetric products are allowed. For a symmetric product upward and downward volumes have to be equal. For asymmetric products, upward and regulation volumes can be different. Two particular cases of asymmetric product are: • when either upward or downward regulation volume is set equal to zero (i.e. the product only covers downward or upwards offers). • When there is a rule linked upwards and downwards offers (e.g. upwards adjustment is 2/3 of downward adjustments)	Adapted from [22]
Validity period of the bid	The period when the bid offered by the FSP can be activated, where all the characteristics of the product are respected. The validity period is defined by a start and end time. The duration should be, at least, the full delivery period of the bid but it could extend over longer periods of time.	Adapted from [10]
Preparation period	The period between the SO request and the start of the ramping period.	Adapted from [10]
Ramping period	The period during which the input and/or output of power will be increased or decreased until the requested amount of power is reached.	Adapted from [13]
Full activation time	The period between the SO activation request and the corresponding full delivery of the concerned product. This attribute is the result of adding preparation time and ramping time.	Adapted from [10]
Delivery period	Period of delivery during which the service provider delivers the full requested change of power in-feed to, or the full requested change of withdrawals from the system.	Adapted from [10]
Deactivation period	The period for ramping from full delivery to a set (pre-agreed) point, or full withdrawal back to a set point.	Adapted from [10]

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Attribute	Definitions	Source
Recovery period	Minimum duration between the end of the deactivation period and the following activation.	Adapted from [10]
Maximum number of activations	Maximum number of times a SO can activate an FSP during a period of time.	OneNet
Mode of activation	The mode of activation of bids, i.e. manual or automatic. Automatic activation is done automatically during the validity period (with little or no direct human control), whereas a manual activation is done at the SO's request.	Adapted from [10]
Quantity	The power (or change in power) offered and will be reached at the end of the full activation time. This quantity can be limited by a minimum and/or maximum amount of power to be included in a bid. The minimum quantity represents the minimum amount of power for one bid. The maximum quantity represents the maximum amount of power for one bid. These values could reflect technical constraints faced by the SO and/or the MO as well as the FSPs.	OneNet
Divisibility	The possibility for a SO to use only part of the bids offered by the service provider, either in terms of power activation or time duration. A distinction is made between divisible and indivisible bids.	Adapted from [10]
Granularity	The smallest increment in volume of a bid.	Adapted from [13]
Maximum / minimum price	Maximum and minimum price the market operator accepts for the clearance of the market	[21]
Availability price	Price for keeping the flexibility available (mostly expressed in € /MW/hour of availability)	[21]
Activation price	Price for the flexibility actually delivered (mostly expressed in € /MWh)	OneNet
Aggregation	This attribute determines whether a grouped offering of power by covering several units via an aggregator is allowed.	[21]
Baseline methodology	Methodology used to estimate the volume of energy delivered by an FSP compared to the case if the product would not have been activated.	OneNet
Measurement requirements	This attribute describes the systems to be used to measure the unit traded as a result of the product.	OneNet
Penalty for non-delivery	This attribute would determine the penalty that the FSP would face if they fail to deliver the energy agreed on the product.	OneNet

4.2 A framework for the product design

This section presents a framework that can be used when designing products. This framework builds on the framework developed by Heilmann et al. [23] which classifies attributes into four different levels of abstraction that are discussed in the following sections. In this deliverable, the framework is extended by, in the design of the product, separating the attributes depending on the actions that SO/MO and FSPs undertake when deciding

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the values of the different parameters. Below, we provide a schematic overview of this framework, seen from the point of view of the SO (Figure 4-1) and the point of view of the FSP (Figure 4-2).

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

Figure 4-1: Framework for products - attribute set by SO/MO

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

Figure 4-2: Framework for products - attribute set by FSP

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4.2.1 Objective of the product

As a first step in the definition of a product it is important to understand the purpose flexibility will be used for, i.e. the product objective. This product objective will include the motivation for the product (i.e. the needs that it is aiming to address) as well as also the users and providers. This motivation, however, does not need to be linked to one single service as a single product could be used to cover multiple services. For example, a product could address changes in the load in the grid that arise as a result of network maintenance. Therefore, the SO will be acquiring additional active energy which could be used to address frequency, congestion and, potentially, voltage issues.

When considering new products, a question is whether the service could be provided by other products. To consider this possibility, we can use the 'Small but Significant Non-transitory Increase in Price' or SSNIP test (also known as the hypothetical monopolist test). This concept is commonly used by competition authorities to identify the substitutes to a given product that limit the capacity of a hypothetical monopolist to increase prices profitably.[5] Considering this SSNIP framework when defining system products helps as this test allow us to understand whether other products would overlap and whether that overlap is significant enough to make some of the products redundant and/or more difficult to obtain as liquidity will be spread over a larger number of products.

To undertake this test, the European Commission defines the process as "a speculative experiment postulating a hypothetical small lasting change in relative prices and evaluating the likely reactions of customers to that increase"[24]. In other words, under this test, a product is fully defined only if a hypothetical monopolist would find it profitable to introduce a Small but Significant Non-transitory Increase in Price (SSNIP).

[5] Note that this concept is normally used in what it is referred as market definition in competition cases. This market definition exercise aims to identify all the different components of a market that would limit the market power of a company. To avoid confusions with the definition of the energy markets, in this section we will not refer to market definition but to it ultimate goal of this tool.

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This analysis is undertaken using an iterative process illustrated in Figure 4-3 below:

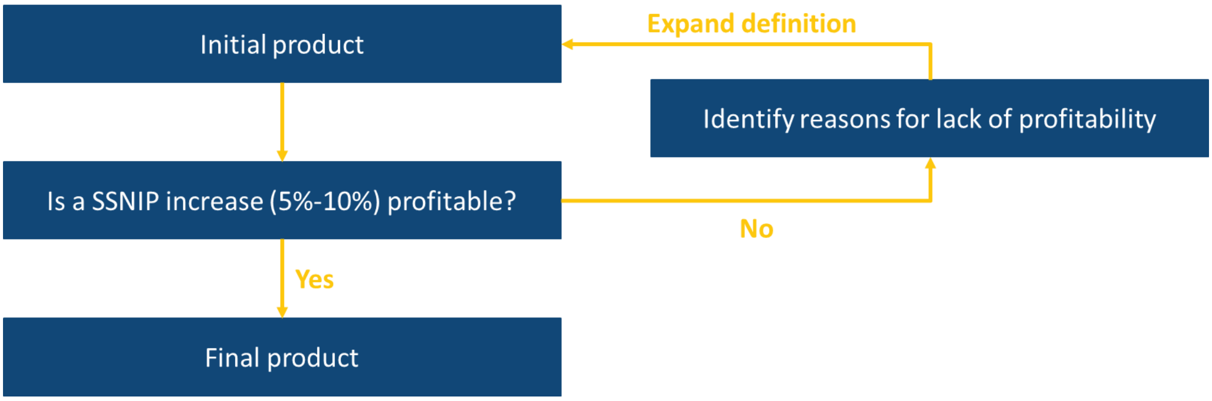

Figure 4-3: Process for SSNIP test

In their analysis, competition authorities normally consider three different sources that could limit the profitability of a SSNIP increase:

- Demand-side substitution – A SSNIP could be unprofitable because buyers (in our case SOs) could decide to buy a different product as the relative prices change.
- Supply-side substitution – An increase in prices could not be profitable if producers of other goods could enter into the market fast enough to remove any profit.
- Geographical dimension – A price increase could be limited by the capacity of the buyer to obtain the same product in a different location.

An example where the reasoning underpinning the SSNIP test has been implemented in energy is the policy by the European Commission to introduce convergence in frequency products across the member states. By promoting this convergence, the European Commission is aiming to ensure that the geographical dimension becomes stronger as increases in price in one member state would trigger a larger volume of imports which would dilute that increase in prices.

Other examples of how this test has been implicitly used in energy can be found in the table below. In that table we have identified, using products presented in previous Horizon 2020 projects, e.g., EU-SysFlex [25], CoordiNet [26], some attributes that have been considered to be relevant enough to generate different products.

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Table 4-2 Rationale for using certain attributes as product differentiators

Source limitation	Attribute	Discussion on effect
Demand-side substitution	Active/reactive power	If the SO requires active power, it could be unfeasible to cover the need with reactive power. Therefore, even if there is an increase in price in the active power product, the SO cannot substitute it with a reactive power product.
Supply-side substitution	Full activation time Means of activation	If the SO requires a certain response time/activation time or communication methodology for the delivery of its services (e.g., a full activation time <5s to ensure that the frequency remains stable), it would not be able to substitute these products with other alternatives.
	Duration of the product	If the SO aims to address a long lasting need (e.g., reducing investment by reducing congestion in peak demand periods), it will be interested in obtaining a long-term contract. If the price of that contract were to increase, providers of short-term contracts could enter into the market. However, there could be a number of barriers to this entrance. For example, not all FSPs can provide the flexibility requirements for the whole duration of a long term contract. Also, it is not necessarily the case that, even at a higher price, the long term contract is profitable for all potential new providers.
Geographical dimension	Requires/does not require location	If the SO requires the product to solve local needs, it is unlikely that they can substitute the product for non-local products, even if there are price increases.

The main characteristic of all these attributes is that they play an important role in SO's ability to use that energy to satisfy its needs/scarcities. However, the reasons why they play such a role are very different. Furthermore, as technology evolves, it is possible that these restrictions would change, resulting in a variation in the definition of products.

4.2.2 Technical dimensions

As discussed by Heilmann *et al.* [23], "the technical description of a flexibility product is of outstanding importance from two points of view: that of the network operator, which needs to evaluate the technical value of the flexibility option in relation to a specific problem; and that of the potential supplier, the FSP, which needs information about whether the assets can technically provide the flexibility and how this can be quantified."

Therefore, in this section, we have included those attributes that impose technical restrictions in the delivery of the product. In the framework, we have divided the technical attributes into three categories, i.e. definition of the traded good, the timing for delivery, and communications. These categories are discussed in more detail below.

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Definition of the traded good

This includes the characteristics of the "good" being traded. When considering what it aims to achieve when acquiring a product, the SO will aim to be more precise than just to say they are acquiring active or reactive power. The attributes included in this section are:

Table 4-3 Attributes included in the definition of the traded good

Attributes
Capacity/energy
Active/reactive energy
Location required
Certificate of origin
Level of availability
Symmetric/asymmetric product
Validity period of the bid

Among these attributes, there is one that requires particular attention as it limits whether the SO has the legal right to use the product directly to maintain the stability of the network or additional procurement will be required before that is possible. This is the attribute that differentiates when the SO acquires energy or capacity[6]. For balancing products, the EBGL [10] defines these concepts as:

- "balancing capacity" means a volume of reserve capacity that a balancing service provider has agreed to hold and in respect to which the balancing service provider has agreed to submit bids for a corresponding volume of balancing energy to the TSO for the duration of the contract [7, art. 2.5].
- "balancing energy" means the energy used by TSOs to perform balancing and provided by a balancing service provider [7, art. 2.4].

If we extrapolate that definition to all products, in a capacity product, the SO is acquiring the insurance that the capacity would be available if it is required to obtain energy.

Based on this capacity/energy attribute, a distinction can be made between capacity and energy products. Depending on the procurement process, three options would be available:

- Energy only option – the SO buys the energy. Therefore, the SO has the legal right to use that product to manage the stability of the network. Even more, when acquiring this product, the SO determines that it will be using that right.

[6] Capacity is sometimes also referred to as availability.

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- Combination of capacity and energy – the SO buys the capacity and the energy. However, depending on the way the energy is acquired, we can find two different alternatives:
    - the SO buys the capacity with the potential to activate the energy when or if required. Therefore, it will have the legal right to use the energy to stabilise its network at any point in time during the validity of the product (following some potential restrictions that will be included in the definition of the product);
    - The SO buys capacity and there is a separate procurement process for the linked energy. (This second procurement could be limited to only those FSPs that had a capacity contract or open to all potential providers to increase liquidity in the market, the so-called 'free - bids').

When choosing between these categories as part of the design of the product, SO will need to consider the advantages and disadvantages of each category presented in the table below:

Table 4-4 Advantages and disadvantages of energy/capacity products

	Advantages	**Disadvantages**
Energy	It could reduce prices when compared with products that include reserving capacity as FSPs will have access to other revenue sources. This product only uses the capacity of the FSP while the product is being delivered. The rest of the time, the FSP can use these assets to provide other services (contrary to a capacity product where these assets are reserved). It could reduce overall costs as the SO only pays for the energy it consumes.	It could increase prices (or even fail to ensure the SO obtain the energy it requires) if there is not enough liquidity in the market. Energy could be unavailable if FSPs decide to sell its flexibility in other products that reserve their capacity. These products would be difficult to use to address situations where the SO's needs require a fast reaction (e.g. unforeseen interruptions in some assets in the grid causing congestion). The SO would need to run a procurement process that would require some time the SO could not have.
Capacity acquired ahead of energy	It could reduce the price of an associated energy product. This product would aim to ensure a certain level of liquidity in the energy market the SO would run to obtain the energy it requires. It could reduce prices when compared with a capacity and energy product as the energy could be obtained in a market where free-bids could bring into additional competition into the market.	It could increase the overall costs as SO will need to pay to reserve the capacity. These products would be difficult to use to address situations where the SO's needs require a fast reaction (e.g. unforeseen interruptions in some assets in the grid causing congestion). The SO would need to run a procurement process that would require some time the SO could not have.

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	Advantages	Disadvantages
Capacity acquired together with energy	The SO does not need to run a procurement process when the need arises. As a result, it could facilitate the reaction when the SO has short reaction times.	It could bring the highest costs among the three options as the SO needs to pay for the capacity and, in addition, there is a reduced level of competition for the energy as there are not free bids when the SO needs to activate the energy.

Another important attribute included in the definition of the good is the validity period of the bid as its interactions with other attributes could generate very different products. To illustrate this interaction, the figure below shows the different time related attributes considered in this deliverable:

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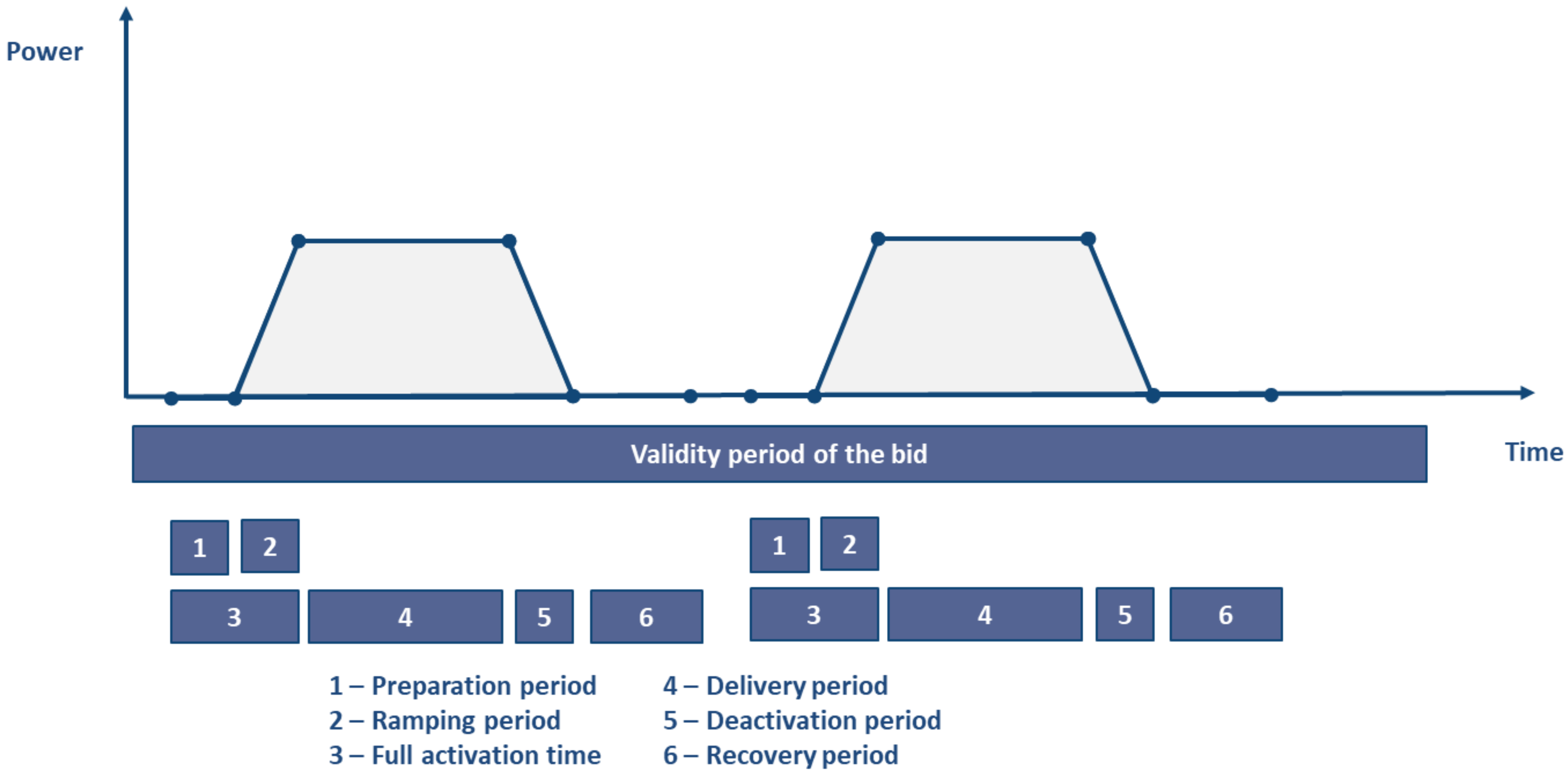

Figure 4-4 Interactions between time related attributes

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This figure shows that, once the product is procured, we differentiate the validity period of the bid (i.e. the period covered by the product) from the different times when the SO communicate to an FSP the activation of the energy included in the contract. As indicated in the figure, this activation process could take place in several occasions during the validity period of the bid.

This differentiation plays an important role. For example, the SO could acquire two products, both of which have 1MW capacity over one year. In the first product, the SO can activate the capacity as often as required but for no more than one hour a day. In the second product, the SO can activate the capacity for no more than 1 hour during the 12 months. The first contract could be used for the daily management of the network while the second one would be used in emergencies.

Timing for delivery

To identify whether certain assets will be able to deliver the product to address a need, it is important to understand whether the speed at those assets can become operative matches the need of the SO. This would refer to the different time components considered when activation takes place as shown in Figure 4-4. The table below includes a list of all attributes included in this category:

Table 4-5 Attributes included in timing for delivery

Attributes
Preparation period
Ramping period
Full activation time
Delivery period
Deactivation period
Recovery period
Number of activations
Preparation period

Communications

When considering whether an FSP can deliver a certain product, it will be important to understand the method of communication the SO expects to use in the communication with the FSP. Therefore, the attribute in the table below needs to be specified:

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Table 4-6 Attribute included in communications

Attributes
Mode of activation

The SO could require automatic communication to ensure that it obtains a fast response to allow the SO to deliver operational services. However, this affects the capacity of most of the FSPs to deliver those services as they do not necessarily have the assets to deliver this form of communication.

4.2.3 Bid related dimensions

The bid related dimensions of the flexibility product focus on the rules and limitations that are introduced in the bids as part of the procurement process. Our definition of product requires that it is tradeable which means that, together with the definition of the technical characteristics, there needs to be a list of attributes that are linked with the way the product is traded, i.e. how bids will be provided.

In this section, we will not enter into all the detail on how the trading is organised[7] but focus on those attributes that could affect the capacity of an FSP to provide a product. These attributes are divided into three categories, i.e., technical rules for the bids, trading-related rules, and temporal organisation of the bidding, which are discussed in the following sections.

Technical rules for the bids

These are attributes that could be introduced to facilitate the operation of the market algorithm. To facilitate the operation of the energy grids and markets, the SO and MO introduce limitations to the bids that FSPs can submit. These requirements are not based on technical requirements that could affect the capacity of the product to deliver a certain service but are focused on the technical requirements that facilitate the development of a clearing algorithm. When determining whether it needs to introduce these attributes, the SO and MO need to balance a trade-off between simplifying the algorithm used to operating the system/market and the effect this can have on the liquidity in the market. For example, if the SO decides to introduce a minimum quantity requirement, some of the FSP could not participate directly into the market which could result in that flexibility not being used.

The attributes included in this category are:

[7] This will be extensively covered in D3.1 of OneNet.

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Table 4-7 Attributes included in technical rules for the bid

Attributes
Quantity
Divisibility
Granularity
Maximum and minimum price
Availability price
Activation price
Aggregation

Settlement rules

These attributes describe the methodology that will be used to evaluate whether the FSP has delivered the product required by the SO. This includes both the measurement requirement and how those measurements are to be used to calculate the variation in the amount of energy put into/out of the system by the provider of flexibility:

Table 4-8 Attributes included in settlement rules

Attributes
Baseline methodology
Measurement requirements
Penalty for non-delivery

4.2.4 Allocation of activities between different agents

When designing a product, it is not only important to understand the different attributes that are relevant but one also needs to consider the role each actor will play in the definition of the values for that product where role and actor are defined as follows:

- the role is the external intended behaviour of a party. Roles describe external business interactions with other parties in relation to the goal of a given business transaction. Parties carry out their activities by performing roles, e.g. SO, trader. Parties cannot share a role.
- the actor is a party that participates in a business transaction. Within a given business transaction an actor assumes a specific role or a set of roles. An actor is a composition of one or more roles and as such does not appear in the model [27]

For example, when considering the Full Activation Time (FAT), the SO in their role as operator of the grid could determine its maximum duration of this attribute, while the FSP, in their role as flexibility provider, will inform (potentially as part of a prequalification process) the SO whether its actual FAT complies with that maximum. Therefore, in this framework, we have divided the relevant attributes depending on how the values of those attributes are determined (i.e., this is the main difference between Figure 4-1 and Figure 4-2)

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5 Development of harmonised products

Within the objectives of this deliverable is the development of harmonised products in the TSO-DSO consumer value chain. These products would reduce the risk of fragmentation of the energy system between markets to facilitate liquidity as well as facilitating the coordination between TSOs, DSOs and consumers. Before considering the identification of these products, it is important to distinguish between the concepts of harmonisation and standardisation. Even when this is explored in more details below, we consider that standardisation is just an extreme case of harmonisation where the relevant attributes are defined using one single value. As a result, in this section, we will normally refer to harmonisation except when the development of a single standard product is required.

This section also presents the framework that we propose to use when harmonising products. More concretely, we propose the use of a proportional approach to harmonisation. As a result, when developing harmonised products, we propose to use an approach that considers both potential benefits and costs/barriers of further harmonising the different attributes of the products being standardised.

Finally, this framework is applied in the identification of harmonised products for OneNet.

5.1 Definition of standards, standardization and harmonisation

In this report, the main difference between 'standardization' and 'harmonisation' lies in the degree of strictness of the standards. Harmonisation involves a reduction in variations, while standardization entails moving towards the eradication of any variation [28]. Indeed, harmonisation avoids a one-size-fits-all approach. It makes the trade-off between too many and too few product standards and avoids inconsistencies between standards [29]. Harmonisation allows service providers (in this case, FSPs) to understand the minimum requirements of the service markets. This in turn allows these providers to offer products for those markets [30]

Within the framework on OneNet, we say that a product attribute is standardised when no divergence is allowed between bidding zones. Therefore, a 'common value' will be agreed for this attribute and it will be used across the whole integrated energy market. An energy product attribute is harmonised when limited divergences are allowed between bidding zones. Therefore, it is possible to observe differences between bidding zones even when these differences would be limited to facilitate coordination.[8]

In the remainder of this document, we will use the word 'harmonisation' which refers to harmonisation and standardization in their strict sense as explained above.

[8] Even when an attribute is harmonised between areas, we would still expect that the attribute is standardised within areas to facilitate the operations of the SOs and FSPs in that specific area

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5.2 Our harmonisation framework – A proportional approach to harmonisation

Harmonisation of system service products is not an easy process as these products are used by a large number of companies with very different initial positions. Therefore, we propose to use a proportional framework that acknowledges these differences. This framework will aim to consider harmonisation as a balance between its potential benefits and its associated costs or barriers.

In this section, we present the main benefits and drawbacks that we have identified for the standardisation of the different system products and discuss whether this could justify different approaches across products.

5.2.1 Potential benefits of harmonisation

Harmonisation offers a number of benefits.

- There can be a **significant cost reduction**. For instance, research on the sharing of balancing capacity has shown that it allows for a more cost-efficient power system operation. The reason for this is that, once a balancing product has standardised attributes, it could be used by multiple TSOs, which in turn allows them to conduct a joint balancing capacity sizing exercise and contract less total balancing capacity, resulting in cost savings [29,31,32] in addition to reducing the procurement costs by reducing the number of the parallel procurement process that need to be organised.
- Harmonised products **reduce complexity** over the different markets. This would make it easier for FSPs to offer their services[9], hence increasing the liquidity in the market and reducing the cost of procuring it. It would also encourage investors in flexibility-providing technologies or FSPs to invest.
- It would **facilitate TSO-DSO coordination** by bringing their products more in line. Increasing the harmonisation of the products across DSO could facilitate their interaction with the TSO. When TSOs interact with multiple DSOs, they could need to understand the position of these different DSOs. Therefore, reducing the variety of products across DSOs, would facilitate their interaction with the TSO as well as between the DSOs themselves. Equally, harmonising products between TSOs and DSOs could be required to simplify the optimisation of the overall energy system.
- It would facilitate the **coordination between SOs and FSPs** because, if products are harmonised, FSPs would find it easier to identify the requirements they need to deliver and they can understand the requirement if they want to submit flexibility bids in different markets which reduces both their learning costs and their bidding costs.

[9] These services could be provided across multiple bidding zones for non-locational products or in different, non-connected markets for locational products.

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- The coordination between multiple TSOs (and potentially multiple DSOs) would result in **improved planning and control** as counter-activations would be avoided. Also, having harmonised products would make it easier to **compare performance** between different bidding zones and FSPs.
- **Facilitate the identification of potential investment in new FSPs** as potential investors can more easily compare different potential investment possibilities.

When considering these benefits, it is important to identify differences between products that could limit the potential for integration and, as a result, the potential to achieve some of the benefits of harmonisation. One such difference appears between frequency and non-frequency products. Frequency products are non-locational and harmonisation can facilitate the trade between bidding areas. On the contrary, non-frequency products have a strong locational component which means that there is a limited potential for trade between bidding areas which would limit the potential benefits of this harmonisation.

As a result, it would appear that the harmonisation of frequency products could bring additional benefits that cannot be achieved with non-frequency products.

5.2.2 Disadvantages and barriers to harmonisation

Harmonisation, however, can come also with some disadvantages which can be summarised in one sentence: harmonisation **reduces the flexibility to cater for national/local market/grid specificities**. By increasing the harmonisation there is a risk that products adapt less efficiently to the local characteristics which could result in less efficient use of the resources. Similarly, it could be that different bidding zones and markets offer **unique opportunities** but that, due to harmonisation, these opportunities are **not acted upon** since all markets and bidding zones must conform to the standard practice [33].

To consider this potential disadvantage in more detail, we consider **common barriers** that could justify that each market is different and must therefore have its distinctive products and/or attributes [31]. Table 5-1 provides an overview of these potential barriers.

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Table 5-1 Barriers to harmonisation in energy products and their attributes (adapted from [31])

Factors limiting harmonisation	Potential effects for product harmonisation
Market characteristics	
Physical environment	The structure/technologies of the grid on a specific bidding zone could impose restriction on the values of certain attributes or the use of certain products. Also, physical characteristics could make harmonisation unnecessary. For instance, Cyprus, being an island, can have completely different products and there is no need to harmonise them until there is an interconnection with other grids.
Stage of economic and industrial development	Historical reasons could have developed the industry in different ways. As a result, different starting positions could justify the development of different products. An example affecting markets could be that harmonisation would require FSPs to make a certain investment to deliver that product (e.g., wind turbines being required to deliver a certain degree of inertia) and that that change would make it more difficult for them to recover their investment.
Cultural factors	When considering harmonisation, it would be important to consider cultural differences between countries, as well as between companies. For example, SOs have a degree of experience (and internal culture) that may differ in respect to alignment with the active management of a network.
Market conditions	
Stage of the product life cycle in each market	Some products are in different stages of their life cycles in different national/regional markets. Such differences in life cycle stages usually call for adaptations of "home country" approaches. Therefore, a more advanced user of a product could resent adapting "out-of-date" values for attributes while a less advanced one could perceive some changes as one step too far.
Competition	Harmonising attributes could reduce the number of FSPs that can deliver the service. This could result in a lack of competition/liquidity which could reduce social welfare.
Market institutions	
European, national and regional regulators	It could be a political choice not to standardize products and attribute values.
SOs, FSPs, BSPs, and their representation at regional, national or European level	There could be political or other reasons not to standardize products and attributes values.
Legal restrictions	The national grid code or specific regulation pose certain limitations or necessary specifications are not included (yet).

When evaluating these barriers, one needs to consider that not all of them represent a permanent limitation. For example, addressing legal restrictions could require changes in regulatory guidelines or changes in

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legislation. The change of a guideline could be achieved with limited effort while legislative changes would require a more complex process. Equally, changes in legislation would be easier to deliver than changes to the structure of the network.

Moreover, one also needs to consider that not all barriers hold equal importance in the specific case of energy product attributes. For instance, while the physical environment, market conditions or legal restrictions may pose real barriers, cultural factors will probably not.

As a result, harmonising products could require an adaptation process with higher degrees of integration being achieved as some of the barriers discussed above are dismantled. However, this does not mean that in the long term a full standardisation is feasible and desirable. Some of these barriers could remain in place in the long term justifying differences between products.

As with the benefits, it would appear that the barriers to integration also justify a higher integration of the frequency products. TSOs have been using these products for a long time which means that they are further in their life cycle. Furthermore, these are well understood products with liquid markets. Non-frequency products are less developed as it is only in recent years with the introduction of RES that DSOs have started considering the need to use those products. This makes it more difficult to develop standards as the companies are further back in their understanding of the products and there are currently limited markets for the delivery of these products.

5.3 Development of harmonised products

With that framework in mind, we started developing the harmonised products we would propose for OneNet.

When defining these products, it will be important to keep at the front of our mind the effect that each decision can have on technological neutrality and the liquidity of the market where the product will be procured. Certain values of some attributes will mean that certain technologies will not be usable for the delivery of that product which exclude those technologies from this potential source of revenue (i.e. it could bias against investing in those technologies) as well as reducing the competition for the provision of that product (i.e. the liquidity in the market). Therefore, when considering the values for each attribute it is important to consider that potential effect. In some cases, these limitations cannot be avoided (e.g. if the limitation arises from the need the SO operating is facing) but, whenever possible the products should be designed to mitigate these limitations.

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To develop these products, it is also important to consider the discussions in Section 5.2. Our analysis there indicates that there is a justification for a difference in approach between frequency and non-frequency products. This is presented in the following table:

Table 5-2 Approaches to the harmonisation of frequency control and non-frequency control products

	Frequency control products	**Non-Frequency control products**
Objectives	To facilitate the development of European markets for frequency control products.	Location requirements limit the potential for integration. Therefore, the objectives are: • to provide clarity for FSP and aggregators aiming to participate in markets; • to facilitate TSO-DSO coordination by reducing heterogeneity between products.
Location	Between TSOs	At least between DSOs but better including TSO
Benefits	Significant increase in reliability and reduction in costs	Facilitate that FSP invest in new flexibility assets by improving transparency and reducing TSO-DSO coordination costs
Barriers	Potential limits due to differences in network structure	Products are in the early development phase.
OneNet approach	Standardisation of the list of relevant attributes Standardisation of values across bidding areas when possible	Standardisation of the list of relevant attributes Harmonisation of values when possible

These differences in the potential for harmonisation have also been reflected in the current efforts being undertaken at a European level. These concerted efforts reflect the requirement by the EBGL to harmonise certain balancing market processes and rules. Recognising the importance of the **buy-in from all the partners and stakeholders** involved, it would be possible to delegate the development of these standards to sector representatives. For example, ENTSO-E has developed proposals supported by (all) TSOs on an implementation framework for the exchange of balancing energy from mFRR and RR, and the establishment of common and harmonised rules and processes for the exchange and procurement of Balancing Capacity for FCR [11,12,14,34].

These efforts have been complemented by the creation of pan-European balancing platforms. These platforms include: Regelleistung.net for FCR [11,34,35], PICASSO for aFRR [13], MARI for mFRR [13] and TERRE for RR [14].

Given that these initiatives already provide highly harmonised products, the focus of this deliverable will be on congestion management and voltage control products, taking the standard for the frequency products from the projects discussed above. The development of these products is discussed in the following sections.

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5.3.1 General assumptions for the harmonised products for OneNet

Followed the approach in CoordiNet 1.3 [21], we have developed some general assumptions when defining the characteristics of some of the product attributes:

- Aggregation will be allowed wherever possible so that a portfolio of FSPs is able to deliver the different services. This should facilitate the technological neutrality of the product as different technologies could be combined to facilitate the delivery of the product.
- The minimum quantity or bid size will be set at 10kW for DSO products or 1MW for TSO products (in case of active power). These values trade-off the technical requirements for the SOs to have quantities that are meaningful for their needs with the capacity of individual FSPs to deliver the product which could facilitate liquidity in the market.
- Asymmetric products will be allowed wherever possible so that all types of flexibility – including all types of FSPs – can participate on an equal footing.
- Along the same line, divisible bids will be allowed when possible.
- FSPs will be paid for all products they provide (i.e. there will be an availability price if the product includes capacity and an energy product when that option is included in the product). These prices will be indicated in euro but recognising that for those countries using a different currency these prices will be set in the local currency.
- Some attributes do not need to be discussed explicitly in the description of the products as they are currently not considered by TSOs and DSOs. These include:
    - certificate of origin; and
    - level of availability.
- Other attributes will not be included as they were identified as not being relevant for the capacity of the FSP to deliver a product. The SO would not need to consider the preparation period and ramping period always that the FSP can deliver the required FAT for the service.
- In addition, the attributes that fall under the categories of settlement rules described in section 4.2.3 above, were not explicitly defined since they are dependent on the market design.

Based on the development process and framework described in the previous sections, the harmonised products for OneNet are presented in the sections below.

5.3.2 Frequency controls products

Based on the work by ENTSO-E and the current definitions of the products in the context of developing TERRE, PICASSO and MARI platforms, the values of the attributes of the frequency control products are presented in the following sections.

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Inertia

Product-based on active energy with very fast activation time (close to real-time) used for reduction of power system oscillations.

Table 5-3 Attributes for inertia products

Attributes	Values
Capacity/energy	Capacity, Energy or both
Location required (Y/N)	No
Maximum full activation time	Instantaneous
Minimum required duration of delivery period	15 seconds
Maximum deactivation period	
Maximum recovery period	
Maximum number of activations (per day, week…)	
Required mode of activation	Automatic
Minimum quantity	Relative to kinetic energy embedded in rotating masses of synchronous unit
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed
Granularity	
Maximum and minimum price	
Availability price (Y/N)	Yes, in €/MW
Activation price (Y/N)	Yes, in €/MWh
Symmetric/asymmetric product (Y/N)	Upwards
Aggregation allowed (Y/N)	No restrictions from aggregation but aggregation could be limited to one point of connection with the grid.

FCR

This product constitutes "active power reserves available to contain system frequency after the occurrence of an imbalance" [36] This is a product that requires a relatively fast response with full activation time <30 seconds.

Table 5-4 Attributes for FCR products

Attributes	Values
Capacity/energy	Capacity, Energy or both
Location required (Y/N)	No
Maximum full activation time	30 seconds

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Attributes	Values
Minimum required duration of delivery period	Each bid can be activated and deactivated at any moment within the validity period
Maximum deactivation period	
Maximum recovery period	
Maximum number of activations (per day, week…)	
Required mode of activation	Automatic
Minimum quantity	1 MW
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed
Granularity	1 MW
Maximum and minimum price	
Availability price (Y/N)	Yes, in €/MW
Activation price (Y/N)	Yes, in €/MWh
Symmetric/asymmetric product (Y/N)	Symmetric
Aggregation allowed (Y/N)	Allowed

FFR

According to the Australian Energy Market Commission (AEMC) [37], Fast frequency response (FFR) refers to the delivery of a rapid active power increase or decrease by generation or load in a time frame of two seconds or less, to correct a supply-demand imbalance and assist in managing power system frequency.

Until recently there was no need for FFR as a market product in Europe because the "natural" inertia in power plants such as hydro and gas would be able to address these needs. The integration of more renewable resources which lack "natural" inertia, such as wind and PV, causes the need for fast responses from new sources.

Table 5-5 Attributes for FFR products

Attributes	Values
Capacity/energy	Capacity, Energy or both
Location required (Y/N)	No
Maximum full activation time	< 2 seconds
Minimum required duration of delivery period	8 seconds
Maximum deactivation period	< 2 seconds
Maximum recovery period	
Maximum number of activations (per day, week…)	
Required mode of activation	Automatic

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Attributes	Values
Minimum quantity	1 MW
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed
Granularity	
Maximum and minimum price	
Availability price (Y/N)	Yes, in €/MW
Activation price (Y/N)	Yes, in €/MWh
Symmetric/asymmetric product (Y/N)	No symmetry required
Aggregation allowed (Y/N)	Allowed

aFRR

Adapting [38], aFRR is "the active power reserves available to restore system frequency to the nominal frequency and, for a synchronous area consisting of more than one LFC area, to restore power balance to the scheduled value" always that the activation takes place automatically.

Table 5-6 Attributes for aFRR products

Attributes	Values
Capacity/energy	Capacity and energy
Location required (Y/N)	No
Maximum full activation time	5 minutes
Minimum required duration of delivery period	Each bid can be activated and deactivated at any moment within the validity period
Maximum deactivation period	≤ full activation time
Maximum recovery period	
Maximum number of activations (per day, week…)	
Required mode of activation	Automatic
Minimum quantity	1 MW
Divisibility (Y accepted / Y required /N)	Each bid shall be divisible
Granularity	1 MW
Maximum and minimum price	
Availability price (Y/N)	If required, in €/MW
Activation price (Y/N)	Yes, in €/MWh
Symmetric/asymmetric product (Y/N)	No symmetry required
Aggregation allowed (Y/N)	Allowed

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mFRR

Adapting [38], mFRR is "the active power reserves available to restore system frequency to the nominal frequency and, for a synchronous area consisting of more than one LFC area, to restore power balance to the scheduled value" always that the activation takes place manually.

Some TSOs (e.g. Norwegian TSO Statnett) intend to activate bids submitted to mFRR standard product market to manage congestions inside bidding zones. To achieve this, Statnett will require BSPs to submit additional information (e.g. location) in the bids that can be used when needed to select and activate bids suitable for handling intra-zonal system constraints. As a result, this would transform this product into a variety of Predictive short term / long-term local active product discussed below.

Table 5-7 Attributes for mFRR products

Attributes	Values
Capacity/energy	Capacity and energy
Location required (Y/N)	No
Maximum full activation time	12.5 minutes
Minimum required duration of delivery period	5 minutes
Maximum deactivation period	To be consistent with requirements set on the FAT and on the minimum duration of delivery period
Maximum recovery period	Defined in terms and conditions for FSPs
Maximum number of activations (per day, week…)	
Required mode of activation	Manual
Minimum quantity	1 MW
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed
Granularity	1 MW
Maximum and minimum price	
Availability price (Y/N)	If required, in €/MW
Activation price (Y/N)	Yes, in €/MWh
Symmetric/asymmetric product (Y/N)	No symmetry required
Aggregation allowed (Y/N)	Allowed

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RR

According to [38], RR is the active power reserves available to restore or support the required level of FFR to be prepared for additional system imbalances including generation reserves. These products can have a long full activation time (<30 minutes).

Table 5-8 Attributes for RR products

Attributes	Values
Capacity/energy	Capacity and energy
Location required (Y/N)	No
Maximum full activation time	30 minutes
Minimum required duration of delivery period	15 minutes
Maximum deactivation period	Under national responsibility
Maximum recovery period	Determined by FSP
Maximum number of activations (per day, week…)	
Required mode of activation	Automatic/manual
Minimum quantity	1 MW
Divisibility (Y accepted / Y required /N)	Divisible and/or indivisible bids allowed (Resolution for divisible bids = 0.1MW)
Granularity	1 MW
Maximum and minimum price	
Availability price (Y/N)	If required, in €/MW
Activation price (Y/N)	Yes, in €/MWh
Symmetric/asymmetric product (Y/N)	No symmetry required
Aggregation allowed (Y/N)	Allowed

5.3.3 Non-frequency products

When developing these products, we have aimed to identify products that are system service agnostic, i.e. they are not linked to any particular system service. This will allow SOs to use these products in the provision of more than one service.

When considering the definition, it is also worth flagging that the core technical difference between these products and those included under frequency products, is that non-frequency products require the inclusion of a locational component. Therefore, if a SO would decide to use a frequency product (e.g. mFRR) to the provision of congestion management by requiring that the bids include the location where the product can be delivered, we would understand that product to be a non-frequency product and, as a result, fall under the definitions in this section.

To define the products in this section, we have first separated between active and reactive power products as this is a technical parameter that will have important effects when it comes for the SO to decide what product to use for each need.

For each one of the active/reactive power products, we have identified three different options in the function of the use and the validity of the bid as shown in the figure below:

		Rationale for the use of the product		
		Unexpected need	Forecast need	Mitigate/delay grid reinforcement
Validity period of the bid	<1 month	Corrective products	Predictive short-term products	
	>1 month			Predictive long-term products

Figure 5-1 Typologies of non-frequency products

For the rationale for the use of the product, we have identified three main groups depending on whether the product is used to:

- react to unexpected system needs;
- react to forecast system needs that arise from either operational activity (e.g. planned maintenance) or improvements in the forecast; and
- React to forecast long term system needs in order to delay / substitute traditional grid reinforcements by acquiring an energy or capacity product.

As it is stated in Section 4.1, the validity period of the bid is the period covered by the product. We have separated between two potential types of products, those that are more oriented towards the operational management of the network, with a validity inferior to one month and those that are more oriented to long term operations and they will last over one month (with potential for this period to cover several months or even multiple years.

More detailed information about products is presented in the following sections.

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Corrective local active product

This product would be used to react with active power to an unexpected incident that requires correction in less than one hour (i.e., FAT should be under one hour). This product will include information about the location of the flexibility.

In some cases, SOs could decide to introduce a variation of the mFRR product discussed above where location information would be included. This new product would then fall under the umbrella of local products and, most likely under this Corrective local active product.

Table 5-9 Attributes for corrective local active products

Attributes	Values
Capacity/energy	Capacity, energy or both
Location required (Y/N)	Yes
Maximum full activation time	<60 min
Minimum required duration of delivery period	A multiple of 15 minutes up to 1 hour
Maximum deactivation period	Defined in terms and conditions for FSPs
Maximum recovery period	Defined in terms and conditions for FSPs
Maximum number of activations (per day, week…)	
Required mode of activation	Automatic or manual (if compliant with FAT)
Minimum quantity	1 MW for TSOs 0.01 MW for DSOs
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed
Granularity	1 MW for TSOs 0.01 MW for DSOs
Maximum and minimum price	
Availability price (Y/N)	If required, in €/MW
Activation price (Y/N)	Yes, in €/MWh
Symmetric/asymmetric product (Y/N)	No symmetry required
Aggregation allowed (Y/N)	Allowed

Predictive short term local active product

This product would be used to react using active power to a forecasted system need within the operational planning timeframe. Therefore, activation can be planned which would reduce the pressure on the full activation period and, as a result, increase liquidity. The product can be acquired as a capacity only (to be combined with an energy product), an energy product or a capacity and energy product. The procurement of this product would

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happen at least once a month (i.e., the duration of the product is under one month) to increase the liquidity in the market. This product will include information about the location of the flexibility.

Table 5-10 Attributes for Predictive short term local active product

Attributes	Values
Capacity/energy	Capacity, Energy or both
Location required (Y/N)	Yes
Maximum full activation time	<60 min
Minimum required duration of delivery period	A multiple of 15 minutes up to 1 hour
Maximum deactivation period	Defined in terms and conditions for FSPs
Maximum recovery period	Defined in terms and conditions for FSPs
Maximum number of activations (per day, week…)	
Required mode of activation	Automatic/ Manual
Minimum quantity	1 MW for TSOs 0.01 MW for DSOs
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed
Granularity	1 MW for TSOs 0.01 MW for DSOs
Maximum and minimum price	
Availability price (Y/N)	If required, in €/MWh
Activation price (Y/N)	If required, in €/MWh
Symmetric/asymmetric product (Y/N)	No symmetry required
Aggregation allowed (Y/N)	Allowed

Predictive long-term local active product

This product would be used to mitigate and/or delay the need for traditional grid reinforcements using active energy. This product could contract capacity (together with energy or alone with the acquisition of the energy left to the following procurement process). The duration of the product could extend over a long period (over a month but it could cover multiple years). Activation can be planned (scheduled delivery) or done at the request of the SO (this could require a separate procurement process if the initial product is a capacity only product). This product will include information about the location of the flexibility.

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Table 5-11 Attributes for Predictive long term local active product

Attributes	Values
Capacity/energy	Capacity, Energy or both
Location required (Y/N)	Yes
Maximum full activation time	24h
Minimum required duration of delivery period	A multiple of 15 minutes up to 1 hour
Maximum deactivation period	Defined in terms and conditions for FSPs
Maximum recovery period	Defined in terms and conditions for FSPs
Maximum number of activations (per day, week…)	
Required mode of activation	Automatic/ Manual
Minimum quantity	1 MW for TSOs 0.01 MW for DSOs
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed
Granularity	1 MW for TSOs 0.01 MW for DSOs
Maximum and minimum price	
Availability price (Y/N)	If required, in €/MWh
Activation price (Y/N)	If required, in €/MWh
Symmetric/asymmetric product (Y/N)	No symmetry required
Aggregation allowed (Y/N)	Allowed

Corrective local reactive product

This product would be used to react with reactive power to an unexpected incident that requires correction in less than one hour (i.e., FAT should be under one hour). This product will include information about the location of the flexibility.

Table 5-12 Attributes for corrective local reactive product

Attributes	Values
Capacity/energy	Capacity, Energy or both
Location required (Y/N)	Yes
Maximum full activation time	<60 min
Minimum required duration of delivery period	A multiple of 15 minutes up to 1 hour
Maximum deactivation period	Defined in terms and conditions for FSPs
Maximum recovery period	Defined in terms and conditions for FSPs
Maximum number of activations (per day, week…)	

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Attributes	Values
Required mode of activation	Automatic or manual (if compliant with FAT)
Minimum quantity	0.01 Mvar or 0.1 Mvar
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed
Granularity	0.01 MVar
Maximum and minimum price	
Availability price (Y/N)	If required, in €/MVar
Activation price (Y/N)	Yes, in €/MVarh
Symmetric/asymmetric product (Y/N)	No symmetry required
Aggregation allowed (Y/N)	Allowed

Predictive short term local reactive product

This product would be used to react using reactive power to a forecasted system need within the operational planning timeframe. Therefore, activation can be planned which would reduce the pressure on the full activation period and, as a result, increase liquidity. The product can be acquired as a capacity only (to be combined with a reactive power product), a reactive power product or a capacity and reactive power product. The procurement of this product would happen at least once a month (i.e. the duration of the product is under one month) to increase the liquidity in the market. This product will include information about the location of the flexibility.

Table 5-13 Attributes for predictive short term local reactive product

Attributes	Values
Capacity/energy	Capacity, Energy or both
Location required (Y/N)	Yes
Maximum full activation time	<60 min
Minimum required duration of delivery period	A multiple of 15 minutes up to 1 hour
Maximum deactivation period	Defined in terms and conditions for FSPs
Maximum recovery period	Defined in terms and conditions for FSPs
Maximum number of activations (per day, week…)	
Required mode of activation	Manual/ Automatic
Minimum quantity	0.01 MVar or 0.1 MVar
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed
Granularity	0.01 MVar
Maximum and minimum price	
Availability price (Y/N)	If required, in €/MVar
Activation price (Y/N)	If required, in €/MVarh
Symmetric/asymmetric product (Y/N)	No symmetry required

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Attributes	Values
Aggregation allowed (Y/N)	Allowed

Predictive long-term local reactive product

This product would be used to mitigate and/or delay the need for additional grid reinforcements using reactive power. This product could include activated reactive power or reserved reactive power (together with the potential for activating the reactive power or alone with the reactive power being procured in the following procurement process). The duration of the product could extend over a long period (over a month but it could cover multiple years). Activation can be planned (scheduled delivery) or done at the request of the SO (this could require a separate procurement process if the initial product only include a reserve of reactive power). This product will include information about the location of the flexibility.

Table 5-14 Attributes for predictive long term local reactive product

Attributes	Values
Capacity/energy	Capacity, Energy or both
Location required (Y/N)	Yes
Maximum full activation time	24h
Minimum required duration of delivery period	A multiple of 15 minutes up to 1 hour
Maximum deactivation period	Defined in terms and conditions for FSPs
Maximum recovery period	Defined in terms and conditions for FSPs
Maximum number of activations (per day, week…)	
Required mode of activation	Automatic/Manual
Minimum quantity	0.01 MVar or 0.1 MVar
Divisibility (Y accepted / Y required /N)	Divisible and indivisible bids are allowed
Granularity	0.01 MVar
Maximum and minimum price	
Availability price (Y/N)	If required, in €/MVar
Activation price (Y/N)	If required, in €/MVarh
Symmetric/asymmetric product (Y/N)	No symmetry required
Aggregation allowed (Y/N)	Allowed

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6 Analysis of the products proposed by demonstrator partners

This section presents the products being considered by OneNet's demonstrations and matches them to the harmonised products presented in section 5.3. As discussed in Chapter 2, to undertake this matching process, we collected information using a questionnaire directed to the partners responsible for each one of the demonstrators. In that questionnaire, they were asked to provide us with the definition of the products they are aiming to test as well as the values for the main attributes.

After considering this information, we organised a workshop to obtain additional clarifications from the different demonstrators. Once the additional information was provided, we undertook an initial matching of the product against our harmonised products. The findings in this initial matching were corroborated with the different demonstrator partners in an additional workshop.

In this section, we present the results of that analysis. It is important to note that since the demonstrators are still ongoing, some of their proposed products may change. Furthermore, it is also important to notice that even if they have not fully set values for some of the attributes, demonstrators have confirmed that their values are expected to be inside of the ranges proposed in section 5.3.

6.1 Northern Cluster

The Northern Cluster is undertaking a joint definition of the products and, as a result, the products were presented for the whole cluster instead of country by country. The table below shows the harmonisation of the proposed products: [10]

Table 6-1 Harmonisation of the products identified by Northern Cluster

Products proposed by Northern Cluster	Description	Harmonised Products
NRT- -P-E (Near Real Time Active Energy)	Energy product used by SOs responsible for frequency and congestion management. Single product for frequency restoration and congestion management. Procured in near-real-time (15min). Activated manually	Corrective local active[11]
ST-P-E (Short Term Active Energy)	Procured day to a month ahead. Active power energy product. Used by SOs for congestion management.	Predictive short term local active

[10] Note that there may be some products described below that will not be tested by the demonstrations of this cluster.

[11] When using as a frequency product, this product will be consistent with the use of mFRR.

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Products proposed by Northern Cluster	Description	Harmonised Products
LT-P-C/E (Long Term Active Capacity/Energy)	Procured months to years ahead. Active power capacity product. Used by SOs for congestion management, frequency and adequacy.	Predictive long-term local active
ST-P-C (Short Term Active Capacity)	Procured day to a month ahead. Active power capacity product. Used by SOs for congestion management and frequency.	Predictive short term local active
LT-Q-C (Long Term Reactive Capacity)	Reactive power capacity product. Used by SOs for voltage control on HV, MV and LV levels. Long term procurement.	Predictive long-term local reactive
NRT-Q-E (Near Real Time Reactive Energy)	Reactive power energy product. Used by SOs for voltage control on HV, MV and LV levels. Procured from intra-day to near-real-time (15min)	Corrective local reactive, Predictive short term local reactive

6.2 Southern Cluster

The Southern Cluster is composed of two demonstrator partners: Greece and Cyprus. The following tables present the product they are aiming to test and the match to our harmonised products.

Table 6-2 Harmonisation of the products identified by Greek Demo

Products proposed by Greek Demo	Description	Harmonised Products
Reactive support	Provide/absorb a certain amount MVarh in specific timeframes in the local distribution grid through optimized coordinated tap change control on the TSO-DSO interface. It can be used to regulate voltage and reduce energy losses in the distribution grid and is linked with voltage control. The reactive support product will be automatically activated and the flexibility resource will provide reactive compensation to the distribution grid when needed.	Corrective local reactive
Predictive congestion management for TSO/DSO product	Provide/absorb of a certain amount MWh in specific timeframes in local distribution grid. This CM product will be automatically activated, and the flexibility resource will provide peak shaving services to the distribution grid when needed. The resources could be connected to both transmission or distribution grid. The activation time could be from 15 minutes to 1 hour.	Predictive short-term local active
Power regulation mFRR	Provide identification of flexibility resources (secondary and available tertiary reserve) more precisely, as well as identification of the flexibility needs in a more precise manner and longer time horizon than it is being done today.	mFRR

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Products proposed by Greek Demo	Description	Harmonised Products
Power regulation RR	Provide identification of flexibility resources (secondary and available tertiary reserve) more precisely, as well as identification of the flexibility needs in a more precise manner and longer time horizon than it is being done today.	RR
Severe state prevention/restoration product	Provide improved identification of severe system states and contingencies that can cause severe system states in a more precise manner and longer time horizon than it is being done today together with the improved identification of flexibility resources, as well as improved identification of the flexibility needs.	Predictive long-term local active

Table 6-3 Harmonisation of the products identified by Cyprus Demo

Products proposed by Cyprus Demo	Description	Harmonised Products
Change of active power (i.e., load shifting, peak shaving)	Provide/absorb a certain amount of MWh in specific timeframes in the local distribution grid. It can be used for avoiding overloading conditions in the distribution grid and is linked with network congestion management. The peak shaving product will be automatically activated and the flexibility resource will provide peak shaving services to the distribution grid when needed.	Corrective local active
Phase balancing	Provide/absorb a certain amount of negative or zero sequences current in specific timeframes in the local distribution grid. It can be used for avoiding overloading conditions by symmetrizing the load conditions among the three phases and is linked with network congestion management. The phase balancing product will be automatically activated and the flexibility resource will provide phase balancing services to the distribution grid when needed. This product could be provided using reactive and/or active power.	Corrective local active Corrective local reactive
Change of reactive power (i.e., voltage regulation, reactive power compensation)	Provide/absorb a certain amount MVarh in specific timeframes in the local distribution grid. It can be used to regulate voltage and reduce energy losses in the distribution grid and is linked with voltage control. The reactive support product will be automatically activated and the flexibility resource will provide reactive compensation to the distribution grid when needed.	Corrective local reactive
Active power rate of change capability (per minute)	Provide a certain amount of MW per minute (MW/min) for a certain time interval. It can be linked with the automatic frequency restoration reserve products. The product can be activated after a set point was sent to the flexibility resource.	aFRR

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Products proposed by Cyprus Demo	Description	Harmonised Products
Rapid active power change product according to system frequency	Droop product: Provide a certain amount of MW according to the change of frequency from its nominal value (MW/Hz) for a certain time interval. It can be linked with the automatic frequency restoration reserve products and can be automatically activated when the flexibility resource detects a certain amount of frequency change.	Inertia product
Power regulation	Provide/absorb a certain amount of MWh in specific timeframes to meet the day-ahead awarded profile for each resource. This offers power generation scheduling control to meet the final nominated energy volume.	mFRR

6.3 Western Cluster

The Western Cluster is made up of the demonstrations from Portugal, Spain and France. The match between the demonstration's products and the harmonised products is presented by country in the following tables.

Table 6-4 Harmonisation of the products identified by Portuguese Demo

Products proposed by Portuguese Demo	Description	Harmonised Products
Products for Intraday Congestion Management for DSO/TSO	For a situation where forecasted power flows violate the thermal limits of the elements of the grid and voltage stability or the angle stability limits of the power system. For congestions that are caused by failures (e.g. switching state changes, ad-hoc active power intervention such as load shedding) and grid- or market-related measures can be procured too. (intraday)	Predictive short-term local active
Products for Day-Ahead Congestion Management for DSO/TSO	For a situation where forecasted power flows violate the thermal limits of the elements of the grid and voltage stability or the angle stability limits of the power system. [Predictive] For congestions that are forecastable (e.g. redispatch, countertrading as well as the use of active power flexibility) grid- or market-related measures can be procured. (day ahead)	Predictive short-term local active
Sustain	It is a flexibility product that provides a scheduled service purchased in advance of the need to ensure the network remains secure and does not go beyond its firm capacity at times of peak demand. The requirement windows for the provision of this product will be scheduled and fixed at the point of contract.	Predictive long-term local active

Products proposed by Portuguese Demo	Description	Harmonised Products
Secure	It is a flexibility product that provides a scheduled service purchased in advance of the need to ensure the network remains secure during certain network conditions close to real-time. Energy itself is only activated when needed. Payments consist of an Arming fee which is credited when the service is scheduled and a further utilization payment awarded on delivery.	Predictive long-term local active

Table 6-5 Harmonisation of the products identified by Spanish Demo

Products proposed by Spanish Demo	Description	Harmonised Products
Day-ahead	To support the network in the event of expected/programmed fault conditions as maintenance work. As the service is required before a network fault, it consists of an Availability and Utilization fee. By accepting an Availability fee, participants are expected to be ready to respond to	Predictive short-term local active
Real-Time	It is used post fault. It is intended to help with restoration following an unexpected failure of equipment. Under such circumstances, the response can be used to reduce the stress on the network. As the requirement is inherently unpredictable, it is based on a premium 'utilization only' service. This will reward a response that aids network restoration but will pay no arming or availability fees. Participants declared available for the Restore service will be expected to respond to any utilization calls within 15 minutes and will receive an associated utilization fee.	Corrective local active
Agreed Activation Product	It is a flexibility product that provides a scheduled service purchased in advance of the need to ensure the network remains secure and does not go beyond its firm capacity at times of peak demand. The requirement windows for the provision of this product will be scheduled and fixed at the point of contract.	Predictive long-term local active
Availability Product	It is a flexibility product that provides a scheduled service purchased in advance of the need to ensure the network remains secure during certain network conditions close to real-time. Energy itself is only activated when needed. Payments consist of an Arming fee which is credited when the service is scheduled and a further utilization payment awarded on delivery.	Predictive long-term local active

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Products proposed by French Demo	Description	Harmonised Products
Near real time corrective local active energy	This is a flexibility product that can be activated in real time as a corrective action in order to eliminate a network congestion. The activation of this product could be done either by the DSO or the TSO, manually or via an order sent by an automation.	Corrective local active product

6.4 Eastern Cluster

The Eastern Cluster is composed by the demonstrator partners from Czech Republic, Poland, Hungary and Slovenia. The following tables summarise their products and match them against our harmonised products.

Table 6-6 Harmonisation of the products identified by Czech Republic Demo

Products proposed by Czech Republic Demo	Description	Harmonised Products
Local congestion management of active power	Flexibility provided through active power management of fleet charging stations of EV.	Predictive short-term local active
Voltage Control by Q management / Reactive Power Management	This product aims to regulate the Voltage and Reactive power according to the requirements of DSO to achieve voltage stability of part of the distribution network.	Predictive long-term local reactive

Table 6-7 Harmonisation of the products identified by Polish Demo

Products proposed by Polish Demo	Description	Harmonised Products
Change in active power (+ & -) (CM + VC)	The volume of active power resulting from an increase and decrease in the demand or decrease generation at the connection point, in reference to the baseline profile.	Predictive short-term local active
mFRR	European standard product.	mFRR
aFRR	European standard product.	aFRR
RR	European standard product	RR

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Table 6-8 Harmonisation of the products identified by Hungarian Demo

Products proposed by Hungarian Demo	Description	Harmonised Products
Change in active power (P) (CM & VC)	P products of the flexibility market will have the same attributes, which are designed in a way to maximize the number of potential bidders, thus no certificate of origin will be necessary, and products will not be separated based on the technology behind the bid. This practically allows generation units (P), storage units (P), demand-side (P) to participate in the same market. The products will be capacity+energy products.	Predictive short-term local active
Change in reactive power (Q) (CM & VC)	Q products of the flexibility market will have the same attributes, which are designed in a way to maximize the number of potential bidders, thus no certificate of origin will be necessary, and products will not be separated based on the technology behind the bid. This practically allows generation units (Q), storage units (Q), reactive power providers (Q) to participate in the same market. The products will be capacity+energy products.	Predictive short-term local reactive

Table 6-9 Harmonisation of the products identified by Slovenian Demo

Products proposed by Slovenian Demo	Description	Harmonised Products
Congestion management and Voltage control via aggregator through a market platform	Locational congestion management service of existing congested secondary MV/LV transformer (substation) Flexibility (capacity) is procured from aggregated demand response (heat pumps) – active power curtailment.	Corrective local active

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7 State-of-the-art and gap analysis on products

This section analyses the state-of-art of products currently implemented in European Power Systems as well as those which are foreseen to be used by TSOs and DSOs. To develop this analysis, we relied on the responses to questionnaires prepared and circulated among both OneNet demonstration partners and TSOs and DSOs members of the ENTSO-E and E.DSO networks.

With these questionnaires (attached in Chapter 0) we collected information from 14 TSOs and 18 DSOs on the following topics:

- System challenges that TSOs/DSOs need to address to ensure the stability of the network;
- Products that are being currently used in the day-to-day management and those that are being considered as part of R&D efforts;
- Possible values/ranges for each of the product attributes; and
- Whether the current products can be acquired from other network providers (e.g. other DSOs or TSOs).

This information was then discussed in one of the workshops undertaken as part of the work in this task, with the aim of facilitating information and positions exchanges between TSOs/DSOs and task leaders on the proposed product framework and harmonised products for OneNet.

In this chapter, we start by considering the responses of TSOs and DSOs separately and then we compare these responses to identify potential synergies between the products required by both SOs.

7.1 TSO products

This section starts by discussing the challenges identified by TSOs (i.e. the difficulties that they would need to address as the result of the current sector evolution). Afterwards, we consider the products TSOs have currently been using as well as those that have been identified as potentially necessary to keep the stability of the future energy system.

The challenges that could affect the safe operation of the transmission system in the short to medium term are summarised in Figure 7-1:

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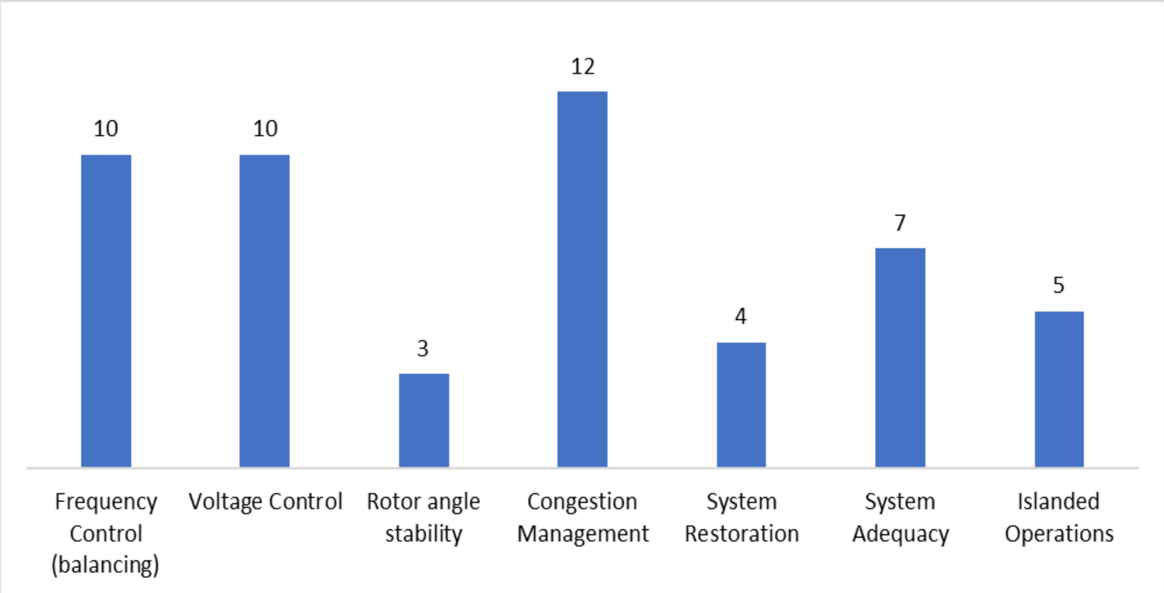

Figure 7-1: Mapping of the main system challenges that TSOs need to address[12]

The numbers in Figure 7-1 correspond to the number of TSOs who have selected a particular system challenge. That figure shows that most of these challenges are consistent with the system services that were identified in Chapter 3. Frequency control (balancing), voltage control congestion management and system adequacy are the major challenges faced by TSOs. Other challenges such as system restoration (i.e. black start) and islanded operations were also discussed in that chapter. Therefore, these challenges match relatively closely with the system services we identified in this report.

The next stage in our analysis was to identify the main products currently in use as well as those that are being considered in the near future to deliver the main system services (i.e. congestion management, voltage control and frequency control). To develop this analysis, we combined the responses to the questionnaires with the work that ENTSO-E is undertaking to develop standardised products (e.g. projects MARI and PICASSO discussed above [11–14]).

The products can be grouped into two big categories as shown in the figure below:

[12] Graph based on responses collected from 14 TSOs.

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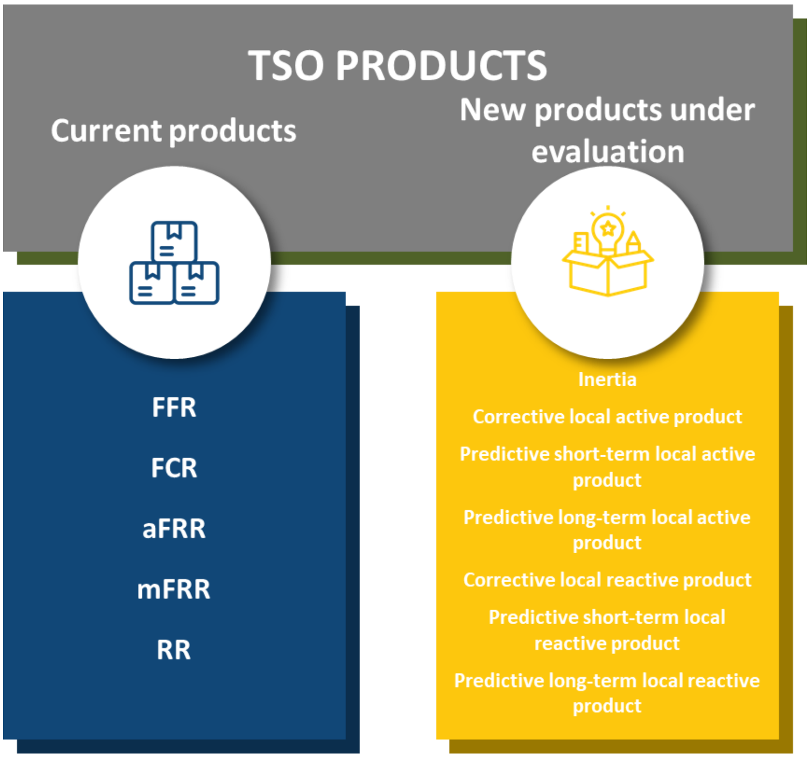

Figure 7-2 TSO current and potential products for the main system services[13]

These products are discussed in more detail in the following sections.

7.1.1 TSO current products

When considering the state of the art for TSO's products, this section considers those where standardisation is already in place or process. These are well understood products and where clear definitions are already in place. These products are summarised in the table below:

Table 7-1 Summary of state of the art analysis for TSOs – current products

Current products	State of the art
FFR	Fast Frequency Response (FFR) is the additional MW output or MW reduction required compared to the pre-incident MW output or MW reduction, which is fully available from a providing unit within 2 seconds after the start of an event and sustainable up to 10 seconds after the start of the event [39]. Until recently there was no need for FFR as a market product in Europe because of the "natural" inertia in power plants such as hydro and gas. The integration of more renewable resources which lack "natural" inertia, such as wind and PV, causes the need for fast responses from new sources.

[13] Note that some of the current products will be used to deliver services with which they share the name. for example, mFRR products will be used for the delivery of mFRR services.

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Current products	State of the art
	This product is not yet in use in the Continental Europe Synchronous Area (CESA) but it is being explored in the UK, the Irish Island and the Nordic countries to deal with the growing uncertainties arising from high levels of RES penetration and situations leading to reduced system inertia.
FCR	This product also called primary frequency control is used by the TSOs to maintain nominal frequency of operation in a synchronous area and is typically provided by generators, storage, and demand response. For about half of the CESA FCR procurement is realized in a common market between Austria, Belgium, Denmark, France, Germany, Netherlands and Switzerland. In addition to those countries, this product also exists in other countries such as Greece. There, FCR represents the collective automatic corrective response of generation units (only generators are providers) to deviations of the system's frequency from the nominal value, aiming at balancing the total generation with the total energy absorption. In this market, FCR is remunerated with a common clearing price which is set at the highest accepted FCR price offer.
aFRR	Automatic frequency restoration reserve (aFRR) is a standard product for balancing energy designed to regulate the Frequency Restoration Control Error (FRCE) to zero. The "Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation" (PICASSO) is the implementation project endorsed by all European TSOs through the ENTSO-E market committee to establish European platform for exchange of balancing energy [1]. As part of one of the demonstrator partners in OneNet, the TSO in Cyprus (CTSO) is aiming to test the introduction of this product.
mFRR	Manual frequency restoration reserve (mFRR) also called tertiary reserve is a product that is activated manually or semi-automatically by TSOs to compensate the imbalances and stabilize the grid. These reserves are the objective of the "Manually Activated Reserves Initiative" (MARI) which is the European implementation project for the creation of the European mFRR platform. Initially 19 TSOs started working under the umbrella of the project MARI. In 2017 they signed a memorandum of understanding outlining terms of cooperation. In a second memorandum of understanding signed in 2018 the membership was expanded to cover 28 TSOs. Since then, four additional TSOs and ENTSO-E have joined the project as observers [2].
RR	Replacement Reserve is a standard product for the provision of both an increase and decrease of active power, with the aim of replacing and/or complementing FRR. Many TSOs that have RRs do so to anticipate imbalances by activating RR before the frequency containment and restoration processes start (i.e. proactive balancing approach).[40] "The European Replacement Reserves Exchange" (TERRE) is the European implementation project for exchanging replacement reserves in line with the Electricity Balancing guideline. The aim of TERRE is to build the RR Platform and set up the European RR balancing energy market to create a harmonised playing fields for the market participants [3]. Currently, the TERRE project consists of 11 TSOs, including operational and non-operational members and observers. It is expected that in the future additional TSOs, using the RR product will join the project as well.

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7.1.2 TSO products under evaluation

To analyse these products, this section matched the products proposed by the different TSOs against the framework of harmonised products presented in Section 5.3 [14] to obtain a common nomenclature for all products. The results of this classification can be observed in Figure 7-3.

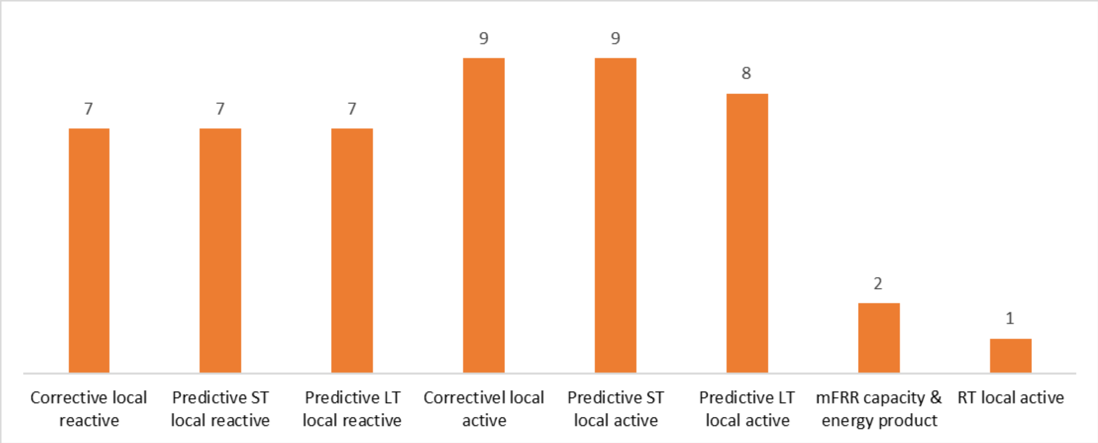

Figure 7-3: Mapping of future products that TSOs consider for congestion management and voltage control

The numbers in Figure 7-3 correspond to the number of TSOs who have indicated they would like to investigate or use these future congestion management and voltage control products. This figure shows that the products delivered using active power appear to receive more attention. Eight of the TSOs indicated they would be using local active products (the information provided did not allow to allocate these products between the three local active power products) while the Latvian TSO indicated that intraday market congestion management (i.e. corrective or short-term active products) will be investigated in more detail under OneNet project.

Furthermore, there is a tendency to reduce the separation between frequency and non-frequency products with some TSOs indicating that they intend to activate bids submitted to mFRR (standard product for balancing market) to manage congestions inside bidding zones after including location information on those bids (i.e. transforming mFRR into a location product). Eventually few TSOs indicated that they would like to use corrective local active products for standing energy reserve. For example, the Greek TSO (IPTO) mentioned that they would like to investigate the use of active power and frequency control products providing standing energy reserve in response to unforeseen disturbances of the system's load balance, in real time during a dispatch. Here we foresee a good match for use of corrective NRT local active product.

This figure also shows that 7 TSOs would like to investigate market-based approach to manage reactive power in the grid and achieve voltage control. As with those for active power, the information provided did not

[14] The assumptions being made for this matching can be identified in Section 11.1

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allow us to distinguish what corresponding timeline would be used for reactive power management by TSO participants.

The following table presents the state of the art of the potential products that TSOs are investigating in the short or medium term. Some of them will be tested within the framework of OneNet demonstrations.

Table 7-2 Summary of state of the art analysis for TSOs – Products under consideration

Products for future harmonisation	State of the art
Inertia	Inertia in generic terms is the capability of rotating machines (including motors) to store kinetic energy and inject it into power system to dampen frequency fluctuations. An inertia decrease can raise the risk of losing system security by risking load-shedding intervention, generators trip, or, in the worst scenario, a blackout situation. For a very short time following a contingency event, the rate of change of frequency (RoCoF) largely depends on the power system conditions prior to the contingency event. In the last few years, the level of synthetic inertia in the system has been under attention since it may be reduced due to increased integration of non-synchronous renewable generation. According to Network Code on Requirements for Generators (NC RfG), relevant TSOs can specify the units or power park modules capable of providing synthetic inertia during fast frequency deviations. TSOs can also specify the operating principle of control systems installed to provide synthetic inertia and the associated performance parameters [41]. Examples of inertia products are beginning to arise in Europe.[15] The Island of Ireland's TSOs (EirGrid and SONI) have introduced a new synchronous inertia service named "Synchronous Inertial Response" (SIR) [42]. In UK, National Grid ESO has specified a remunerated system service relying on the provision of inertia [43]. The provision of the service is organized under a tender process that started on 2019, for a service provision to start between April 2020 and April 2021 and for a contract to run until March 2023 or March 2026. Due to high reliability requirement, the participation is restricted for synchronous compensators and synchronous generators running in a synchronous compensator mode.
Corrective local active product	A corrective local active product is activated after an unexpected fault and it can be used for the provision of services that do not require a location component (e.g. FCR, aFRR or mFRR) as well as location related services such as congestion management and (potentially) voltage control using active energy.

[15] Similar products have also been introduced in some parts of Australia.

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Products for future harmonisation	State of the art
	Of the 9 TSOs[16] that indicated that they would like to investigate market-based approach for local products based on active energy, one is particularly relevant for this product. The Spanish TSO (REE) has expressed their interest in the use of corrective operational product. The REE intends to use it to reduce the stress on the network after a fault (for example, restoration following an unexpected failure of equipment or counterbalancing of re-dispatched energy). REE will be submitting a proposal to NRA (after end of May 2021) after consultation with Spanish stakeholders. Based on initial exchanges during consultation, it would appear that this product would not need to be traded in a market (i.e. it would not be a product under the definition in this document) as REE foresees that this power can be obtained freely with very few investments. The procurement of this product will be applicable to all participants in the intra-zonal re-dispatching market(s) that wants to voluntary participate in post-contingency mechanism.
Predictive short-term local active product	Predictive short-term local active product is procured in day-ahead and intraday timeframes primarily with the objective of dealing with forecast challenges. It will be mainly used for congestion management (Day-ahead congestion management) and balancing (FCR, mFRR, aFRR). However, it could also be used for inertia and voltage control. As for the corrective short term local active product, the Spanish and the Portuguese TSOs have been explicit in the aim to consider this product. Currently in Spain, all market parties are mandated to participate in the provision of this product for congestion management. REE selects the less costly redispatch and indicates the physical units and programming units affected. Redispatches are paid-as-bid. REE will be integrating article 12 and 13 of EU regulation 2019/943 establishing a new framework and procedure for automatic reduction of active power to prevent post contingency congestion [44]. This will lead to conditions for increased participation of demand side resources with storage in congestion management and increased efficiency. REE is currently updating the proposal and it will be submitted to Spanish NRA by mid-2021. This product will be used by REN in case of congestions that are forecastable (e.g. redispatch, countertrading as well as the use of active power flexibility) and grid or market-related measures needs to be procured. (day ahead).
Predictive long-term local active	Predictive long-term local active is a flexibility product that provides scheduled service purchased in advance to ensure the network remains secure. The requirement windows for provision of this product will be scheduled (months or years ahead). This product is in alignment with the services described in the ENA's Open Network Project on Service Definitions document, use in UK [45]. Portuguese and Spanish TSOs (REN and REE respectively) both intend to use these products as a pre-fault mitigation measure.
Corrective local reactive product	Corrective local reactive product is activated after an unexpected fault and it is primarily use for voltage control, even when it could also be used for corrective congestion management.

[16] PSE(Poland), Elering (Estonia), AS AST(Latvia), Tenet (Netherlands/Germany), Fringrid (Finland), TSOC (Cyprus), CEPS (Czech Republic), REN (Portugal and REE (Spain)

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Products for future harmonisation	State of the art
	As indicated above, 7 TSOs[17] indicated that they would like to investigate market-based approach to manage reactive power. Two of those considered the possibility of introducing corrective local reactive products: Estonian TSO (Elering) and the TSO in Cyprus (CTSO).
Predictive short-term local reactive product	The predictive short-term reactive product is procured in day-ahead and intraday timeframes primarily for voltage control, but it could also be used for congestion management. Both Estonian TSO (Elering) and the Finnish TSO (Fingrid) are considering these products. The Finnish TSO is even considering testing competitive auction for reactive power management (instead of other procurement methods such as grid connection agreements) within OneNet demonstration.
Predictive long-term local reactive	Predictive long-term reactive power product can be procured several years ahead primarily for voltage control but also maybe congestion management. Both the Estonian TSO (Elering) and the Greek TSO are considering using this product. In Greece, generators may be requested to produce or absorb power to help manage system voltages close to their point of connection. Currently, voltage regulation is a centrally operated system service, provided by the TSO to all the grid users (production and consumption). The provision of the voltage control ancillary services in many TSOs is currently not remunerated. Compensation, if any, is often defined in the grid connection agreements.

7.2 DSO products

This section presents the state of the art of DSO products. This section starts by discussing the current stage of DSOs regarding challenges identified in their system (i.e. the difficulties that they would need to address as a result of the sector evolution). Afterwards, we consider the products that they have currently in use as well as those products they are evaluating.

Based on questionnaires (included in section 11.3) and discussions with the demonstrator partners, this section gathers information from 18 DSOs from 14 countries (including both DSOs that are partners in OneNet and some DSOs that are members of E.DSO).[18] The first outcome from that information is to observe that not all countries are at the same stage concerning the definition of DSO flexibility products. This is consistent with the assumption in Chapter 5 that non-frequency products (most used by DSOs) cannot be fully standardised at this stage as different countries are at different stages of the product definition cycle.

Potential sources for this difference in developing speed could arise from the current state in the flexibility market of the countries, policies and regulations in place as well as the technological and innovative state of the grid. Furthermore, these differences in situation could also arise from differences between the approaches taken

[17] IPTO (Greece), Elering (Estonia), AS AST (Latvia), PSE (Poland), Fringrid (Finland), TSOC (Cyprus) and CEPS (Czech Republic).
[18] A full list of respondents by country is included in the Appendix in Section 11.2

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by DSOs. Some DSOs could decide to wait until these needs materialise in their network while others could decide to invest in flexibility now to facilitate their reaction when/if the needs materialize.

For example, in the DSO's questionnaire, two DSOs from Germany and Austria mentioned that currently there is not yet a flexibility market in operation in their countries, so no products are being defined by these DSOs. In Austria, an expert group from the TSO-DSO sector is working to analyse the needs and to define the services which might be needed in the future. This will be the basis for the following products definition. In Germany, currently, there are not tradable flexibility products and the market for flexibility products is under evaluation by the government and the regulator.

The questionnaire and the information gathered from demonstration partners also shows that the DSOs current system challenges are mostly related to congestion management or/and voltage control. However, in the questionnaires, it was also asked to DSOs if "Is there any other system challenge that your company is / will need to address going forward?", some of the DSOs indicated that there were other system challenges. Figure 7-4 shows the main challenges identified by the respondents:

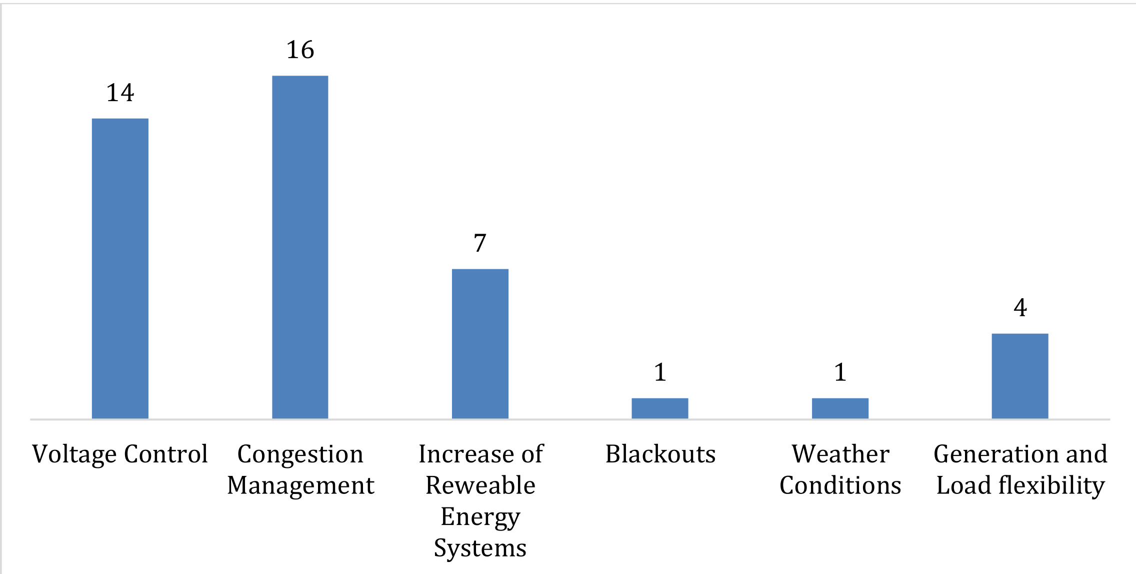

Figure 7-4 Mapping of main challenges that DSOs have

This figure shows that, as for TSOs, the main challenges arise from system needs that constituted the base of the system services identified in Chapter 3 (e.g. needs to deal with challenges like voltage control, congestion management and blackouts). However, DSOs also identify other challenges such as those arising from the construction of the connections for generation and load flexibility.

With the system needs identified, Figure 7-5 summarizes the products DSOs are considering. The left side, blue section, shows the products regarding congestion management and voltage control that are currently being

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applied by DSOs inside and outside of the project. The yellow section shows those products that have been identified by a small group of DSOs but that are still under evaluation by DSOs. All the products are described in more detail in the next sub-sections 7.2.1 and 7.2.2.

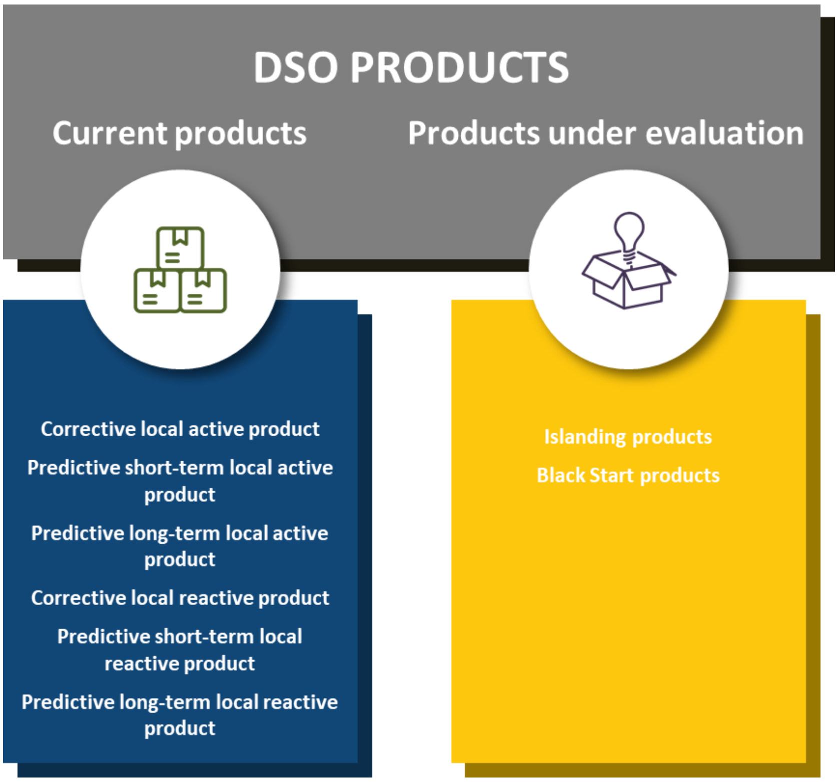

Figure 7-5 Products identified for DSOs

7.2.1 DSO current products

The figure below summarises the responses from the different DSOs in relation to the products that fit into the list of harmonised products presented in chapter 5. The numbers in Figure 7-6represent the number of DSOs working in each product regarding congestion management and voltage control.

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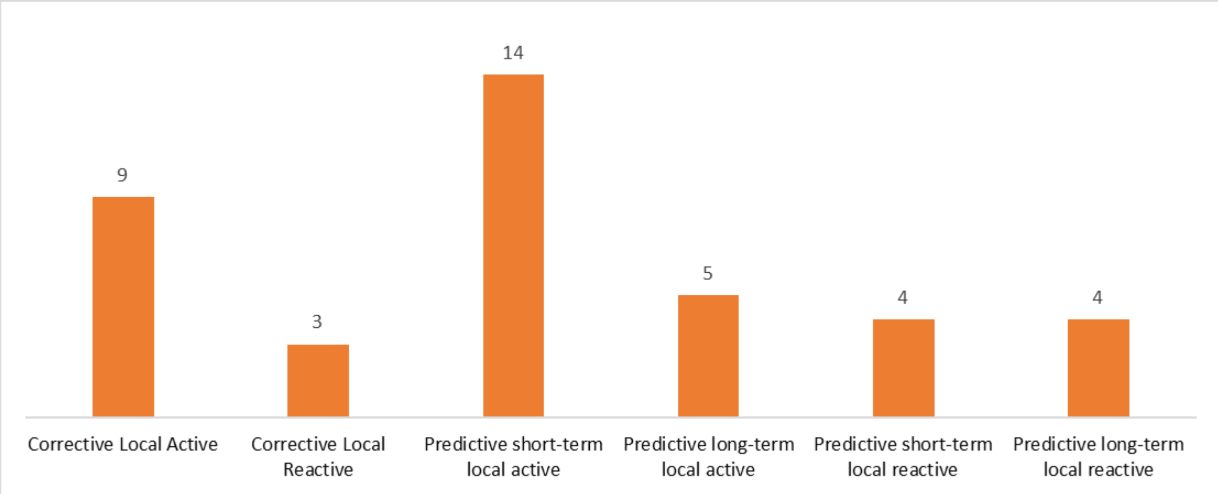

Figure 7-6 Summary of responses about DSO's products

This graph shows that for these DSOs predictive short-term local active is the product most procured to answer mainly to congestion management issues. The findings for each one of these products are presented in more detail in the table below.

Table 7-3 Summary of state-of-the-art analysis for DSOs – Current products

Harmonised DSO Products	**Analysis**
Corrective Local Active	This product would be used to react with active power to an unexpected incident that requires correction in less than one hour (i.e., FAT should be under one hour). These products are being considered by three of the DSOs in our analysis: • In the Cyprus demo, the DSO considers two types of procurement for the same product. • In Slovenia, the DSOs procure products from the aggregator to solve congestion and voltages issues. • In Spain, the two DSOs also aim to test the procurement of this product for congestion management issues in real-time, as described in the Western Cluster section.
Predictive short-term local active	This active power product would be used to solve forecasted problems within the operational planning timeframe. Therefore, activation can be planned ahead which allows the use of FSP that require longer FAT and, as a result, increase liquidity. This product has been identified in six of OneNet's demonstrator partners (more detail in Chapter 6): Greece, Portugal, Spain, the Czech Republic, Poland and Hungary.

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Harmonised DSO Products	Analysis
Predictive long-term local active	Predictive long-term local active power products are procured to deliver congestion management services and, to a less extent, voltage control services that are already pre-scheduled or reserved as an integral part of the of the long-term planning resulting from the organic growth of the network. These products will be tested by four of the demonstrator partners (more detail in Chapter 6): Greece, Spain, Portugal and the Czech Republic.
Corrective Local Reactive	Corrective local reactive power products are procured mainly to solve voltage control issues in real-time. In Cyprus and Greece, as presented in the Southern Cluster in section 6.2, the DSO is aiming to test two versions of this product. The products are the change reactive power for voltage regulation and phase balancing that is also answering to congestion management issues. In Estonia, to solve voltage control and (potentially) congestion management issues, the DSO would procure corrective products.
Predictive short-term local reactive	Predictive short-term local reactive power products are procured with a frequency inferior to one month to answer mainly to voltage control issues even if they could be used for congestion management. Three of the demonstrator partners in this project are aiming to test these products: Estonia, Hungary and Lithuania.
Predictive long-term local reactive	Predictive long-term local active power products are procured to answer mainly to voltage control issues that are already forecasted over a long period. These products could be used to integrate flexibility into the planning process. Three of the demonstrator partners in OneNet are planning to consider these products: the Czech Republic, Estonia and Lithuania.

7.2.2 DSO products under evaluation

This section discusses some of the products proposed by DSOs that do not directly link to the harmonised products identified in Chapter 5. These products aim to address system services that were not considered in detail in this deliverable (e.g. Black start) or that are addressed with a combination of some of the system services identified (e.g. islanding products). These products have been identified in other projects such as the CoordiNet project D1.3 [21] or the EUniversal project [46].

Table 7-4 Summary of state-of-the-art analysis for DSOs – Products under consideration

Non-Harmonised Products	Analysis
Islanding Products	These products are to enable parts of the grid to function independently, which is essential in cases where it becomes difficult to provide energy to these areas. These products could be a combination of harmonised products aimed to address the specific situation of islanding. Flexibility could ensure

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Non-Harmonised Products	Analysis
	power supply to all or a part of the clients affected by a service interruption, forming a microgrid, if endowed with adequate services and control functionalities. This can be relevant for clients and DSOs alike, with these kinds of challenges, potentially improving the reliability and resilience of the system. The Portuguese and Greek DSOs despite not applying this product in OneNet, see it as a potential product to be procured for management in the distribution system.
Black start Products	Applied in situations when islanding is not viable, or in case of a partial blackout in the main grid, due to unexpected extreme events, existing or innovative storage systems could restore service to a local microgrid until reconnection to the main grid is possible. In terms of technical requirements, these systems need to have black start capability in addition to being able to provide fast frequency and voltage services described for the Islanding service. Here, adequate communication between the DSO and all parties involved is also required to guarantee stability during restoration procedures and ensure that the active and reactive powers are within limits.

7.3 Identification of similar products for TSOs and DSOs

As described in this chapter, TSO and DSO products, either currently implemented or foreseen to be, are to address the current and future needs at both transmission and distribution levels. When defining these products, it will be important to consider the interactions between TSOs and DSOs to ensure that all SOs procure these products in a market as liquid as possible. As a result, it will be important to consider the potential alignment of similar needs and look for solutions that facilitate market and grid coordination between TSO and DSO.

Based on the analysis in section 7.1 and 7.2, this section aims to evaluate similarities between the products being considered by TSOs and DSOs. The focus of this section will be on non-frequency products as frequency products will almost exclusively be used by TSOs. To illustrate the potential for similarities, Table 7-5 shows the numbers of TSOs and DSOs using the non-frequency harmonised products:

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Table 7-5 Number of TSOs and DSOs using non-frequency harmonised products

Harmonised Products	TSOs using these products	DSOs using these products
Corrective Local Active	9	9
Predictive short-term local active		14
Predictive Long-term local active	8	5
Corrective Local Reactive	7	3
Predictive short-term local reactive		4
Predictive Long-term local reactive		4

This table shows that products using active energy are those most frequently identified by both TSOs and DSOs. One message that came clearly from the responses and in conversation with the OneNet's demonstrators' partners is that when considering these products, it will be important to ensure interoperability with frequency products (i.e. consistency between attributes) so that flexibility can be used efficiently between different services.

When considering the interoperability of these products, it will be necessary to consider what this means for both TSOs and DSOs. For example, some TSOs indicated that they would like to use a modified version of mFFR product including location for congestion management. If this product is used for congestion management, it might increase liquidity for the congestion management market. However, depending on the definition of the product, it might also add barriers to DSOs because of the strict technical and prequalification requirements of mFRR product. These technical requirements are not necessarily required for congestion management purposes at the DSO level. Therefore, if the technical requirements are introduced by DSOs, they could constitute a major barrier for some of the flexible resources connected to the distribution network [19]. However, as will be discussed in Chapter 8, this challenge could be bypassed using an alternative approach to the definition of the products.

It is also clear from the responses that the definitions of the different products should allow for a product to have multiple use cases and to be used in more than one service. To illustrate this, it is worth considering the products being defined by TSOs and DSOs in the Greek and Portuguese demonstrator partners in OneNet. These products will be procured in both demonstrator partners to address congestion management but they could also be used to provide voltage stability. It is worth noting that the products being procured in these countries are the same. Therefore, besides the harmonisation between both SOs, alignment will be achieved between two countries in distant geographical locations.

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Regarding products based on reactive power, there also appear to be an interest coming from both TSOs and DSOs. Reactive power base products have become more complex with increasing penetration of distributed energy resources as well as with the shift from radial MV and LV networks with unidirectional power flow to meshed topologies. TSO-DSO coordination is especially needed in the provision of these products as reactive power actions carried out by DSOs can affect the TSOs (or other DSOs) and vice versa. Some of that coordination can be done via the definition of the products. For example, in the Greek and the Czech demonstrator partners, the DSOs use a predictive long-term local reactive product, to regulate voltage according to the requirements of DSO to achieve voltage stability in the distribution grid system and reactive power flows at the primarily TSO/DSO substation.

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8 Potential evolution of the services and products

Given the changing nature of the energy sector, one can expect that the definitions of services and products will not remain static. To ensure that these potential changes are in the best interest of consumers, this chapter analyses how system products could evolve and what this evolution could mean for the efficiency of the market and subsequently for consumers.

The objective of this analysis is to support regulators and legislators in identifying (i) the potential advantages and disadvantages of changes in product definitions and (ii) the requirements these changes could impose on the regulatory and legislative frameworks. As a result, regulators and legislators would be in a better position to steer these changes as they start to materialize.

Furthermore, the analysis in this chapter also broadens the discussion of Chapter 5 on harmonised products. That chapter focuses on the development of harmonised products based on the level of disaggregation that SOs are currently considering. In this chapter, however, we extend that analysis one step forward by analysing the effects of further harmonisation - and potentially full standardisation – for products to cover a broader range of services.

8.1 Potential approaches to the standardisation of products covering different services

There are two main approaches when considering the standardisation of products across different services:

- **More restrictive product definition:** This is the case when one product must fulfil the requirements for more than one system service. For example, one way of being able to use mFRR for congestion management is to add the location to the list of attributes to be included. Then, if FSPs would not be able to provide the location of the flexibility source, they would not be allowed to participate in the joint mFRR – congestion management market. This type of product would have a longer list of required standardised (i.e. fixed) list of attributes and harmonised/standardised attribute value. By making the product definition more restrictive to use it for multiple services, it becomes a more versatile product for the SO but a more restricted product for the FSP (as more attribute values would need to be adhered to).
- **Less restrictive product definition:** This is the case when one product must fulfil the requirements for at least one system service and the SO will need to consider whether the product can be used to deliver its needs. For example, the FSP submits a bid including certain attributes and it is up to the SO to use this product for frequency control or congestion management depending on its specific needs at each point in time. This type of product would have a standardised (i.e. fixed) list

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of product attributes, but contrary to the previous approach, the values for the attributes would not be harmonised/standardised. By making the product definition less restrictive, this approach broadens the market in the sense that a larger variety of FSP could bid in the market.

It is important to note that these two approaches are not mutually exclusive. As it is discussed below, it is possible to combine products with broader and narrow definitions such as to allow the provider of flexibility the choice to facilitate it can provide its flexibility into the market.

These two approaches can be depicted using two extreme approaches: the 'superproduct' approach as an extreme case of a more restrictive product definition, and the 'supermarket' approach as an extreme case of a less restrictive product definition. Both concepts were first introduced in EU-SysFlex D 3.1 [47]:

- **The 'superproduct' approach**: "There is […] some scope for defining a very broad 'superproduct' and allowing market participants/portfolio to procure and deliver relevant volumes to TSOs and DSOs through a single provider or an aggregation of providers."
- **The 'supermarket' approach**: "One attractive alternative to SO-defined standard products is allowing providers to declare their capabilities to meet an overall System Services requirement set out by TSOs and DSOs."

Therefore, with a superproduct, the SO would be able to acquire one product to address any of its system needs, while in the supermarket approach, the SO would need to identify which one of the FSPs in the market would provide the most efficient way of covering its need. In other words, in the first approach, FSPs need to aggregate their flexibility to deliver the superproduct, while in the second one, it is the SO who needs to "aggregate" the different sources of flexibility to cover its service needs. Therefore, the difference arises from a different allocation of the responsibility of aggregating the different flexibility sources to facilitate the delivery of system services.

In what follows, we will consider these two approaches in more detail. We start by comparing the current situation with the potential evolution in product definitions as presented above. Next, we present the advantages and disadvantages of the different approaches to the evolution of the market, as well as potential approaches to mitigate the most challenging disadvantages of each approach. To finalise, as the superproduct and supermarket are extreme cases, we present some potential middle ways that could have interesting properties as future product structures.

8.1.1 Comparison of the current approach with potential evolution in product definitions

In this section, we compare the current allocation of responsibilities for aggregation of flexibility to the ones under the two extreme cases discussed above. When presenting the current allocation of responsibilities, the

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approach presented applied especially to TSO once that currently, DSOs use a limited number of system services. However, based on the discussion with the demonstrators in this project, it would appear that DSOs are following a similar approach to the one currently in use for TSOs. Therefore, the discussions below apply to both TSOs and DSOs.

Figure 8-1 provides an overview of the three approaches with regard to how flexibility sources are put forward in the market and acquired by SOs. Generally speaking, FSPs provide their product offers (in aggregated form or not) to the market, where they are selected by the SO to deliver a certain service.

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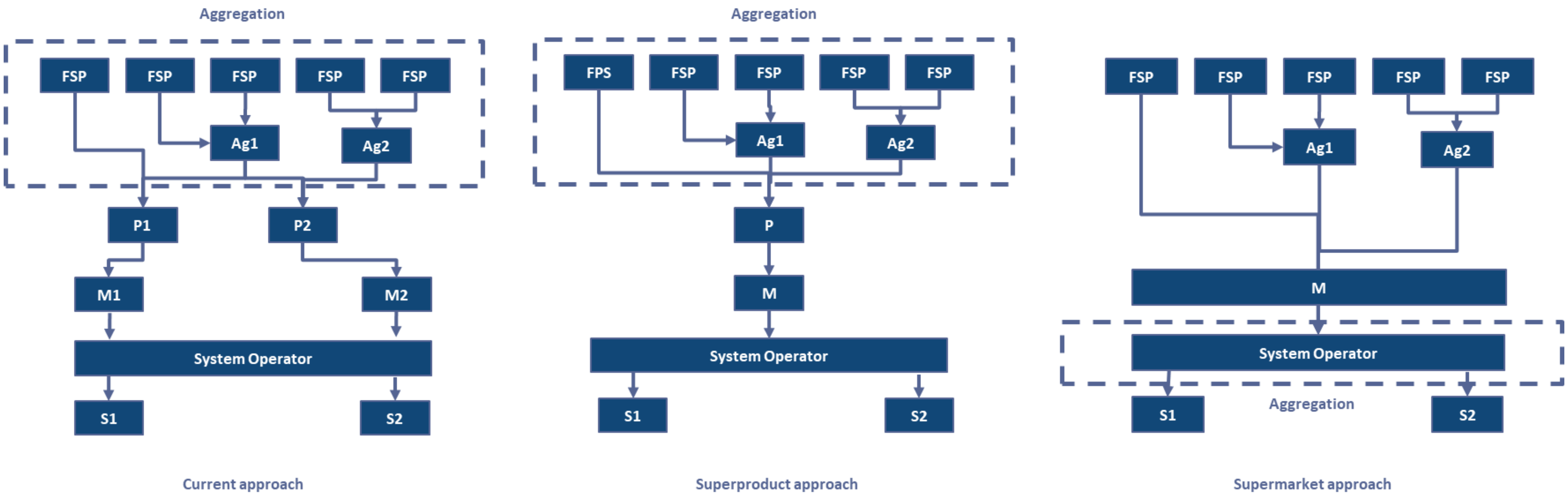

Figure 8-1 Comparison of the different approaches with respect to the responsibility for aggregation

(FSP = flexibility service provider, Ag = aggregator, P = product, M= market, S = service)

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Considering the structures from left to right, we first observe the **current approach** (left on the figure). In that approach, there are a number of products and FSPs are required to aggregate their flexibility to comply with specific requirements for each product. Products offers are submitted to the relevant markets. The SO selects the necessary product offers based on a merit order and, for location-specific products, a location. It then uses the acquired flexibility to deliver the relevant services if and when needed.

Second, in the **superproduct approach** (middle of the figure), a more restricted product definition is in place. Instead of multiple products for multiple services, there is only one product that covers the need for multiple services. Therefore, the responsibility for aggregation lies with the FSP as it needs to ensure the aggregated product fulfils the required standardised values of the (standardised list of) product attributes. The product offer is submitted in the relevant market and the SO, after market clearing, is free to use the acquired flexibility depending on the type of service provision that is needed.

Finally, in the **supermarket approach** (right on the figure), FSPs submit their offers to the market including a standardised list of attributes. The SO will use this information to pick and choose the sources of flexibility that better fit its needs at each point time. In this case, we assume that there is no pre-defined product and the FSPs just provide the SO with the information that this SO needs to be able to choose between the different offers to ensure the stability of the network. The responsibility for aggregation lies with the SO, who has to select the relevant offer for a specific service need.

When considering whether any of these alternatives would be preferred by TSO or DSOs, we have identified a number of conflicting incentives. First of all, TSOs are not directly connected with final consumers (i.e. their networks do not arrive at the final consumers). As a result, if the market only includes FSPs directly connected to the SO's grid, the TSO could prefer a supermarket approach as it will have a small number of bids to consider and, at the same time, it will allow FSPs to provide all the flexibility they have available (i.e. nothing is excluded due to requirements of the product).

However, this is likely to change if this market covers both the TSO's and the DSOs' networks. In this case, the process of selecting with a supermarket approach would be more complex as it would need to consider all bids from FSPs directly connected to TSOs and DSOs. The operation of this system would be sensibly more complex as large FSPs would mix with a growing number of small FSPs with more limited supplies of flexibility. As a result, in these cases, the TSO could prefer a more restrictive definition of the product that would reduce the complexity of the selection between FSPs.

Therefore, if the TSO can cover most of its needs for system products using FSPs connected to its network, it could prefer a supermarket approach but if it were to depend on FSPs connected to the whole system, it would prefer a more structured product approach.

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For a DSO, these effects are similar, i.e. it is easier to select between bids if it only has access to FSPs connected to its network. However, the characteristics of the FSPs directly connected to its network are different with a larger number of small providers of flexibility. Therefore, DSOs could prefer to introduce a larger structure on the products even in this case to facilitate that they can select between the different options.

A second effect arises as TSOs focus on frequency management and congestion management while DSOs focus on congestion management and voltage control. Therefore, location plays a more relevant role for DSOs. DSOs could hence find a supermarket approach more attractive as they can divide the market for location, reducing the complexity of selecting the right FSP. This partition of the market could come with the risk of a potential increase in market power as markets cover a smaller area. This effect, however, is unlikely to be significant as, even if the market were to cover a larger surface, the SO will still need to buy from the limited number of FSP in the area where the needs arise. For example, if in one area there is only one FSP that can address congestion in the network, that FSP has market power independently of the market it operates.

As a result, it would appear that both TSOs and DSOs would have incentives to have some structure on the products if operating an integrated market like the ones for frequency products. However, for those needs where location is relevant, a supermarket could help to bring forward the additional use of FSPs using a supermarket approach.

8.2 Advantages and disadvantages of the potential harmonisation approaches

In this section, we analyse the advantages and disadvantages of the proposed approaches to the allocation of responsibilities for aggregation of flexibility. Table 8-1 provides an overview of those effects for the supermarket and superproduct approaches. These effects would be milder as the application moves away from these extreme cases. The colour of the cells indicates if the effect is positive (green), negative (red) or ambiguous (amber) for the relevant approach.

Table 8-1 Overview of the advantages and disadvantages of the potential harmonisation approaches

Potential effect	Superproduct approach	Supermarket approach
Computational complexity of the real-time management of the network	This option **facilitates the real-time management of the network** as it allows the SO to choose between a limited number of options (i.e. products) that can deliver a certain need. This limits the computational complexity required to identify the right FSP(s) required in each case.	This option makes **real-time management more complex** as the SO needs to optimize, in real-time, across all FSP(s). Therefore, the algorithm will need to be able to choose between all the FSPs to identify those that are able to deliver the need required and, afterwards, optimize the options between them.

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Complexity of the structures of the bids	This option could **reduce the complexity of the bids**. Each FSP could have flexibility available at different points in time. By requiring that FSPs aggregate their offers, this option could result in situations where different FSPs integrate flexibility available at different points in time. As a result, they would be able to use fewer complex bids.	This option could **increase the complexity of the bids** that FSPs would put forward. By considering individual FSPs, the bids would need to account for their availability over time and, as a result, they could result in more complex bid structures.
Individual market transparency/simplicity	This option **simplifies the market**. The products that SO will be able to acquire will be homogenous. As a result, the market will only need to generate one single price for each product. This means the operations of the market are likely to be simple and transparent.	This option **increases the complexity of the market**. The SO would need to deal with a market with very heterogeneous products. As a result, obtaining a price for each one of these products could increase the complexity of the market making it less transparent.
Access to the FSPs by the SO	This option could reduce the number of FSPs the SO can access as: • Some of the flexibility could be unavailable as FSPs could be unable to aggregate their capacity to provide any of the products for the SO. • FSPs can only sell their flexibility using one product. Therefore, they could be disregarded for delivery of a service as their flexibility was not in the relevant product.	This option allows to increase the number of FSPs the SO can have access to as: • FSPs would put forward their availability and the SO will choose between these options. As a result, the SO can have access to flexibility that before it would not have been available as it does not fit into any of the products. • the SO will be able to choose the best flexibility available without concerns about specific products.
Cost efficiency of the FSPs	This option **could reduce the cost efficiency in the delivery of system services**. By increasing the need to integrate the flexibility of the FSPs, there could be situations where less cost efficient FSPs are used as part of a bundle while there are more efficient FSPs available that are not used as they are in a different bundle.	This option **could increase the cost efficiency in the delivery of system services.** By giving the SO the choice across all different FSPs, it will be able to select those that allow the SO to ensure the stability of the network at the lowest costs.
Facilitate the coordination between different flexibility needs	This option **facilitates the integration between different services**. By allowing that a product serves more than one service, this approach would allow the network operator to operate its network without the need to consider what product to activate.	This option **facilitates the integration between different services**. This approach would allow the network operator to choose the option(s) that best matches its needs.

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Market liquidity (ignoring effects on investment)	This option would **reduce the liquidity available in the market**. Those FSP that cannot aggregate their flexibility services to the point where they can provide system services would be excluded from the market. The number of attributes an FSP needs to deliver increases with the number of services that product will cover. As a result, the number of FSP able to provide the product decreases with the complexity of the product which will result in a reduction in liquidity.	This option **increases the liquidity available in the market**. It imposes a reduced burden on FSP which means they will be able to put forward their flexibility services. At that point, the burden is on the SO to ensure that it selects those FSPs that better match its specific needs. This approach reduces the number of attributes an FSP will need to comply with to be able to provide this product. As a result, more FSP will be able to put forward their services, increasing the flexibility in the market.
Incentives to invest in flexibility *Effect 1*	This option could **reduce the incentives to invest in flexibility**. Small investors in flexibility would have to undertake a **bigger effort to unlock the potential revenues from flexibility** (i.e. they face higher entry costs). As a result, they would be less likely to invest.	This option could **facilitate the investment in flexibility**. By facilitating access to the provision of services, **FPs could have access to additional revenue sources**. Therefore, they would find it more profitable to invest in new flexibility sources.
Incentives to invest in flexibility *Effect 2*	This option could fail to provide the right price signals to incentivize investment. By imposing additional requirements in the aggregation of flexibility, it could introduce a bias towards technologies that are easier to aggregate. Furthermore, by making it more difficult to participate using small sources of flexibility, it could act as a barrier to the introduction of smaller investments.	This option could **provide the right price signals to incentivize investment**. Since this approach introduces fewer limitations in the needs for aggregation and it facilitates that all technologies can provide these services. As a result, it could **facilitate that the prices reflect the right signals**. However, this depends on whether the algorithm used to clear the market can avoid any distortion (e.g. the algorithm could try to minimize the number of sources required to deliver the service which would distort the selection and, as a result, the price signals).
Technology neutrality	The SO could **introduce technological biases** due to the selection of the aggregated product. The SO could introduce requirements in this product that could not be provided by all the technologies. Also, the need to aggregate the products could mean that some of the more difficult to aggregate technologies become less interesting for FSPs.	The SO would **not introduce a technological bias per se but achieving full technological neutrality can be a challenge**. The supermarket approach would not introduce a technological bias as all technologies would be able to qualify. The main challenge will be to ensure that the selection process used by the SO does not introduce rules that would distort the selection of technologies.
Coordination between TSOs and DSOs	This option could **facilitate the coordination between TSOs and DSOs**. By limiting the number of products, this	This option could **require additional coordination between TSO and DSO**. By treating each provider of flexibility as

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	option means that TSOs and DSOs would need to coordinate over a limited number of products which would limit the amount of information they need to share.	one single product, the TSO and DSO would need to share information about each activated provider of flexibility. In some cases, this could just require high levels of integration of the dispatchment of TSOs and DSOs. This is currently very challenging as the IT systems used by TSOs and DSOs are often proprietary and not necessarily compatible between them.
Data security	This **option reduces the of data security risks**. With superproducts, there is less data being transferred between the FSP/aggregator and the SO. For example, the data required to aggregate the different sources of information is kept by the FSP providing the product and there is no need for the SO to receive the data.	This option **increases the data security risk**. The SO needs all the relevant information from the FSP/aggregator to be able to select and aggregate the relevant FSPs. Therefore, the data will be in two different locations and there could be breaches during the transfer.
Requirements of the technical pre-qualification processes	This approach would **reduce the requirements of the technical pre-qualification phase of procurement but it could increase the complexity of these tests**. To pre-qualify providers under this setting, the SO only needs to check whether the combined FSP can deliver the product. Therefore, there is a reduction in the number of tests the SO will need to undertake. However, these tests will not only need to consider whether the aggregator/FSP can provide the product but also the resilience of the aggregation mechanism. As a result, the complexity of the tests could increase.	This approach would **increase the number of technical pre-qualifications the SO needs to undertake but this pre-qualification could be simpler**. The SO would need to test all SO but then the aggregation would not need to be considered as that is done using the SO's systems.

8.3 Changes in products and regulation/legislation

In this section, we will aim to identify the main barriers to the introduction of a supermarket or superproduct approaches and how this could be addressed. We recognise that addressing these barriers could require some changes in regulations and legislations. However, a detailed analysis of these regulatory changes is outside of the scope of this deliverable.

8.3.1 Potential barriers to the development of the superproduct approach

The largest challenge to be tackled when FSPs aggregate demand is that some of the FSPs could be unable to participate in the market which would reduce the potential liquidity in the market. To mitigate this barrier, it would be important to ensure that there are no barriers to the creation of aggregators or energy communities

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and their participation in the market. These agents will be able to combine the flexibility of smaller FSPs to facilitate that more of the flexibility can be included in the superproducts required by the SO.

8.3.2 Potential barriers to the development of the supermarket approach

The largest challenge when the SO chooses between the different sources of flexibility is the need for high computational capacity. Even if this is not currently possible, future developments in algorithm design, as well as computational capabilities, could make it feasible. To reduce this barrier, SOs could aim to mitigate the amount of management done in real-time by, for example, improving their forecasting methodologies. This would allow running the optimization approach at set points (e.g. in parallel to the intra-day markets). However, this could come at a cost as it would require an increase in the security margins. Furthermore, by introducing adjustment earlier, it could need to rely on markets run before real-time which could reduce their liquidity.

In addition to computational challenges, there is the challenge of the generation of a price(s) as the SO will be acquiring heterogenous "products" for which creating a merit order would not be feasible. To generate the price the SO could use a system of pay-as-bid where bids are selected based on the calculation of the minimum price that could address an issue. In the case of location-related services, this would require identifying all potential bids in the relevant area and optimise across those potential options to minimise the overall costs.

8.4 Potential combinations of products

In this section, we describe four potential combinations of products that fall in between both extremes of superproduct and supermarket approach.

8.4.1 Superproduct approach for mFRR and congestion management

One specific case that is currently often discussed and analysed is the procurement of a version of a mFRR product that includes locational information. This product would aim to deliver both frequency and congestion management services. This approach is a first step towards a superproduct approach. The joint procurement of frequency management and CM services was discussed in detail in Deliverable 3.2 of EU-SysFlex [17].

Figure 8-2 presents a graphical overview of what this approach would look like. FSPs would aggregate their flexibility sources into offers to either provide the 'locational mFRR superproduct' in the designated market (P1 and M1 in the graph) to deliver frequency management (mFRR) or CM services, or to provide other products (P2 to Pn and M2 to Mn in the graph) to deliver other services (S3 to Sn in the graph).

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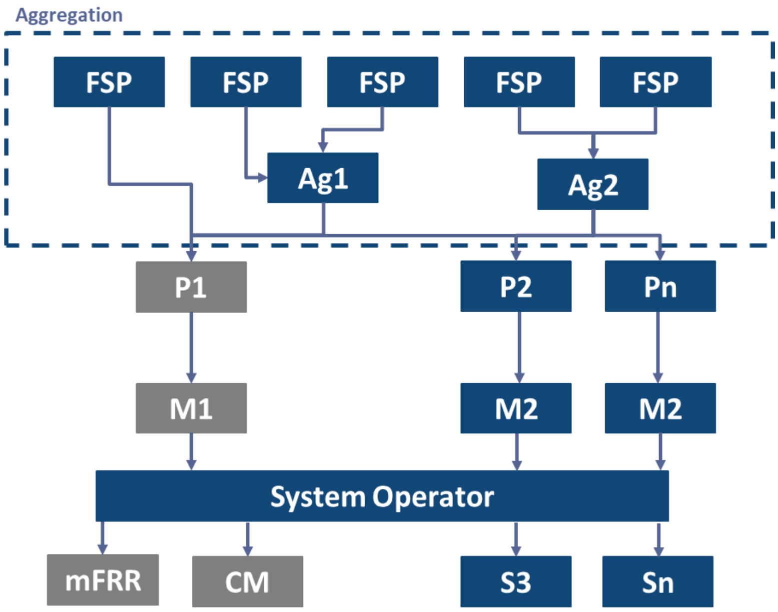

(FSP = flexibility service provider, Ag = aggregator, P = product, M= market, S = service)

Figure 8-2 Graphical representation of the superproduct approach for mFRR and congestion management

Figure 8-2 presents the advantages and disadvantages of this frequency management-CM superproduct-based approach, as discussed in EU-SysFlex [17].

Table 8-2 Advantages and disadvantages of mFRR-CM superproduct-based approach (Source: [17])

Advantages	Disadvantages
Placing combined offers for both services reduces transaction costs and increases liquidity.	The joint algorithm and/or the coordination between SOs is much more complex.
A lower flexibility volume is needed due to the use of flexibility to solve both mFRR and CM.	A joint gate closure time (joint market) for mFRR and CM could exclude certain FSPs and hence reduce the liquidity in the market.
Joint bidding could decrease strategic behaviour.	

8.4.2 Supermarket approach for active/reactive energy

This set-up consists of a supermarket-based approach with two groups of 'supermarkets', i.e., one for active and one for reactive energy. FSPs submit their flexibility offers/availabilities (through aggregators or not) in either the market for active or the market for reactive energy. The SO then is responsible for the aggregation of the offered flexibility and selects the offers most relevant to deliver the service that is needed. This set-up allows for a simple approach for FSPs which could facilitate entry into the market, while at the same time providing the SO with a clear division and a simplified market. Figure 8-3 presents a graphical overview of this approach.

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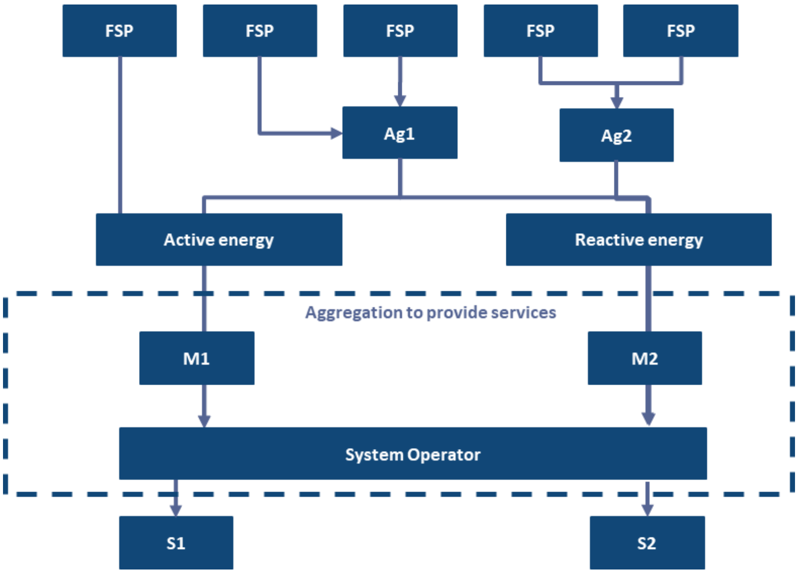

(FSP = flexibility service provider, Ag = aggregator, P = product, M= market, S = service)

Figure 8-3 Graphical representation of the supermarket-based approach for active and reactive energy

There are, of course, a number of advantages and disadvantages connected to this type of approach for active and reactive energy. Table 8-3 provides an overview of these advantages and disadvantages.

Table 8-3 Advantages and disadvantages of an active/reactive energy supermarket-based approach

Advantages	**Disadvantages**
It creates a market where FSPs can easily take part: • could increase liquidity and improve efficiency • could increase investment by allowing new sources of revenue for FSPs • could simplify the dispatching decisions as it SOs separate the two types of power	It would increase computational complexity as SOs would need to identify the right FSP Could increase complexity in the types of bids needed Could increase data risks
It could be technology neutral.	It would require additional coordination between TSOs and DSOs.
	In particular at medium and low voltage: active and reactive power are interlinked.

8.4.3 Supermarket approach for active/reactive power with active power classified based on activation time

A third example builds on the previous example explained in Section 8.4.1. The difference with that previous example is that, in the current case, the active energy product is further split into two separate products based on the activation time. The FSP would hence need to choose between three products. The SO would still need

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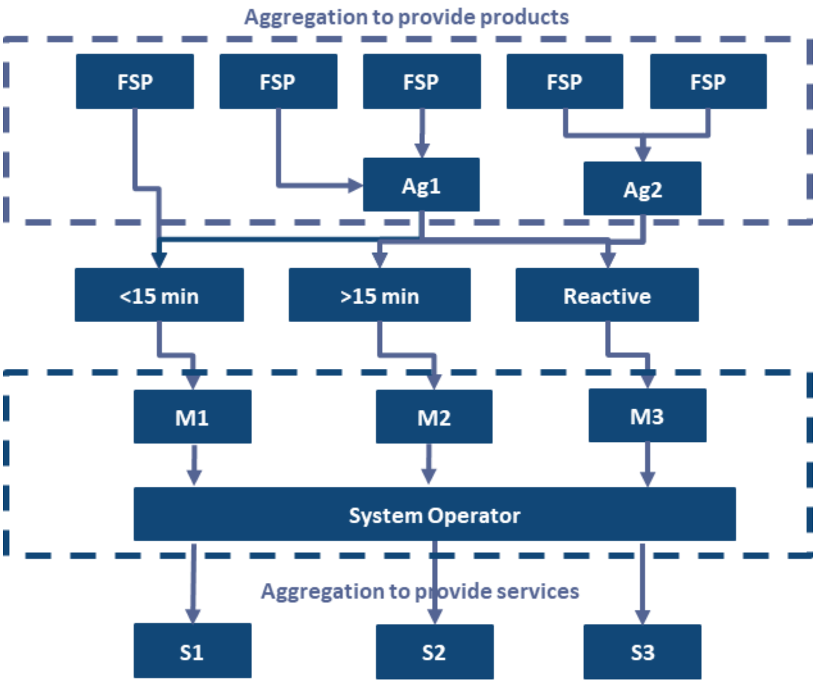
to aggregate the flexibility offers as currently, SOs have several products differentiated based on the different activation times (e.g., FCR, aFRR, mFRR, RR). Nevertheless, compared to the previous example, this approach makes it easier for SOs to have access to a faster and slower range of active energy products. Figure 8-4 provides a graphical overview of the approach. The advantages and disadvantages are similar to the ones in the previous approach (see Table 8-3) but there is a higher degree of complexity involved.



(FSP = flexibility service provider, Ag = aggregator, P = product, M= market, S = service)

Figure 8-4 Graphical representation of the supermarket-based approach for active and reactive energy with active power classified on the basis of activation time

8.4.4 Hybrid approach for frequent/infrequent services

The fourth approach is more of a hybrid model and proposes to standardise some of the most frequently used products (e.g. frequency restoration reserves, FRR) while the rest of the SO's needs would be delivered using a supermarket approach. In this case, the FSP would have to choose between aggregating its supply to provide the harmonised products or submitting its flexibility offers in the supermarket-style market. The SO, in turn, could use harmonised products for those needs that arise often but keep the flexibility of a supermarket approach for other, less frequent needs. This approach would then actually be a combination of the two extremes, i.e., on the one hand, the standardised FRR product would be a type of superproduct that can cover multiple needs, and on the other hand, the SO would have the supermarket approach for fewer frequency services. Figure 8-5 presents the graphical representation of this approach.

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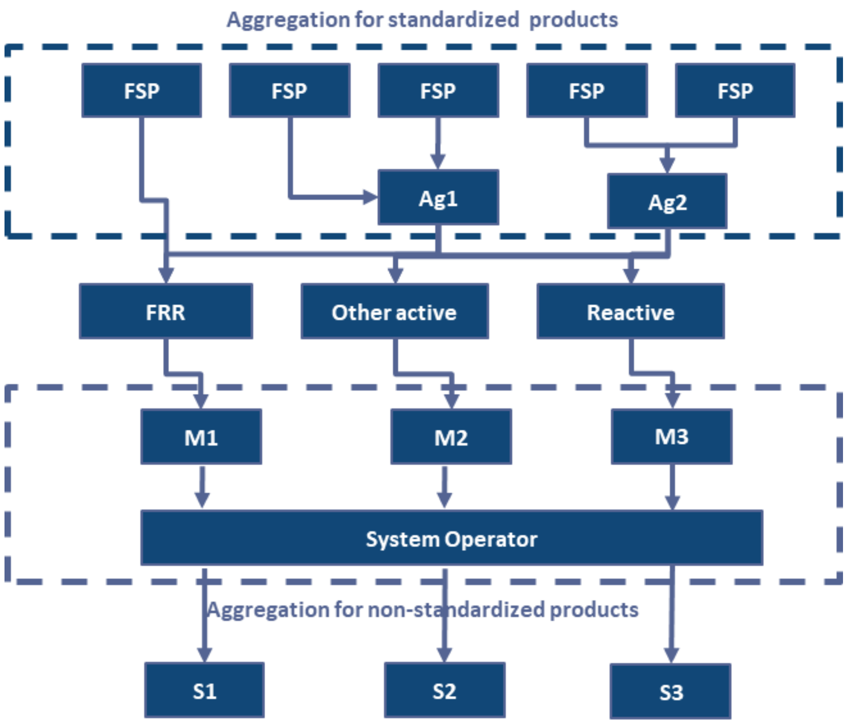

(FSP = flexibility service provider, Ag = aggregator, P = product, M= market, S = service)

Figure 8-5 Graphical representation of the supermarket-based approach for frequent/infrequent services

As was the case for the other approaches, this approach comes with a number of advantages and disadvantages. These are discussed in Table 8-4below.

Table 8-4 Advantages and disadvantages of a frequent/in-frequent supermarket-based approach

Advantages	**Disadvantages**
It allows FSPs to choose whether to offer their flexibility directly or to aggregate it • Aggregated products would be used more often but require an effort • Disaggregated products would allow FSPs to have access to revenues without the additional effort to aggregate their flexibility	It would increase the overall complexity of the system.
This could: • Increase partially cost efficiency and liquidity • Facilitate investment • Create a transparent part of the market	It could create potential biases for/against some technologies as active consumers could prefer technologies that are easier to aggregate as those will bring the possibility of taking part in both the standardised and the supermarket part of the market.
At least one platform (NODES) already offers this functionality.	

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9 Conclusions

This report presents the findings of the analysis undertaken when developing a set of harmonised products for system services in the TSO-DSO-consumer value chain as part of OneNet's Task 2.2. This work also included the matching of the products being considered by the demonstrators in this project as well as a state of the art analysis.

To develop the harmonised products, we identified the system services these products will need to address. To identify these system services, we developed a framework that allows us considering different definitions for system services. The use of a flexible framework is important as the definition of system services needs to be dynamic as new needs, and their associated system services will arise as the energy system keeps evolving. Furthermore, there is not one single correct classification of system services but different classifications could be appropriate depending on the reasons underpinning the development of that classification (i.e. different projects could require different system services definitions as they have different focuses).

To identify the harmonised products that we propose for the delivery of these system services, we started by developing a framework for the creation of flexibility products. This framework set three main questions that will need to be considered in the identification of these products. These questions are presented in the figure below:

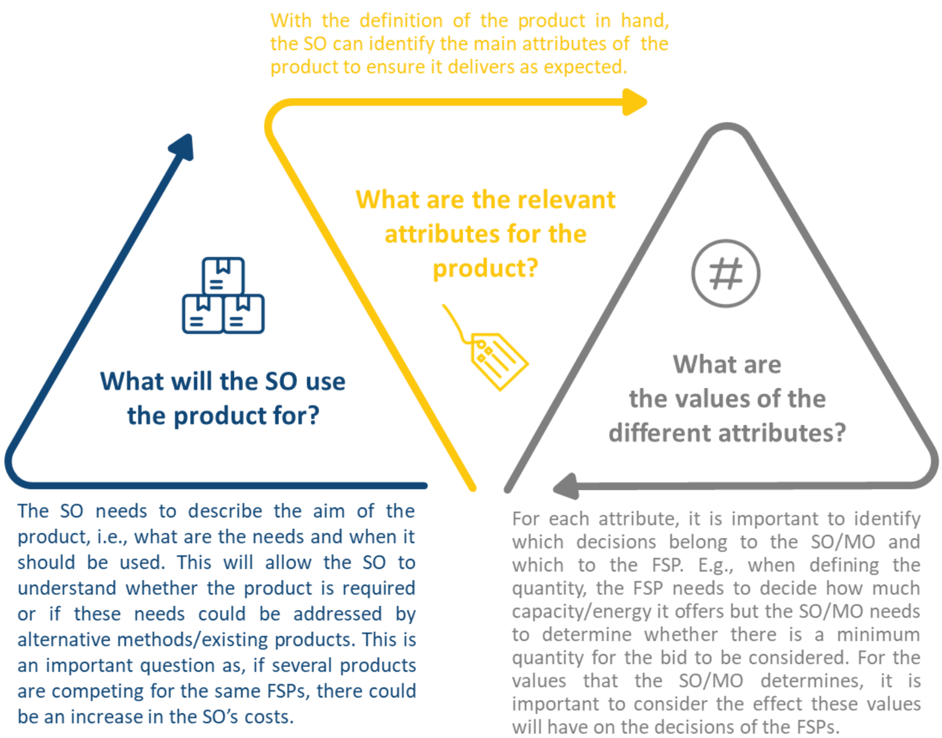

Figure 9-1 Product framework

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To develop harmonised products with that framework, we also evaluated the potential for different levels of harmonisation. In fact, in this report, we introduced the concept of harmonised products. These are products where there is some degree of convergence but where there is still margin for differentiation between the products. Under this definition, standard products are just one extreme option inside of a spectrum (i.e. standard products are fully harmonised products). To identify the level of potential harmonisation, we evaluate its potential benefits and compare it with the costs that would need to be considered to surpass any harmonisation barrier. Only in those cases where the benefits surpass the costs, it would be advisable to increase the harmonisation between products.

When considering harmonisation of flexibility products, it is important to keep in mind that harmonisation can take place in two dimension: harmonisation across the products used by SOs and harmonisation across the products that are used in the delivery of different system services. In the first case, the harmonisation of a product will mainly focus on reducing the variety in the attributes of a pre-determined product across the different system operators to facilitate the coordination between their networks. In the second case, the focus will be in defining a product that can be used across multiple services to ensure that the energy system can obtain the efficiencies that can arise from the synergies in the procurement of these products.

In this report we often consider these potential ways of harmonisation separately. However, when appropriate we also consider the potential interactions that could arise between these two potential approaches to harmonisation.

Even if it is not possible to fully generalise the main benefits of and barriers to harmonisation as these are product specific, we can introduce some important findings from our analysis:

- The potential benefits of harmonising products could be reduced when these products are used to address needs that are specific to a location (e.g. needs to reduce congestion). The harmonisation of these products will still have positives effect as they would facilitate TSO-DSO coordination, DSO-DSO coordination as well as the investment decision-making by FSPs. As a result, harmonisation could still improve the efficiency of the system. An special case that needs to be consider is when products are harmonised not only across SOs but also across multiple services with some of those services not having a local component. In this case, the local component will only be relevant for some of the needs the product can address. As a result, when considering the potential for harmonisation, it is important to consider that, for the non-location related needs, harmonisation would facilitate the inter-regional trade while for the needs that have a location component, the harmonisation would benefit the coordination between different SOs.
- There are cases where products are developed to address very local problems. In those cases, harmonisation could reduce the value / capacity of the product to deliver the actual needs.

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Therefore, as reflected in regulation, harmonisation across these products could have negative effects.

- DSOs are still developing their understanding of the needs that are arising with the growing number of DER while TSOs have been addressing these challenges for a longer period of time. Harmonising the products used by the DSOs have the additional risk that the harmonised product could follow the requirements of the TSO (where more information is available) while it could (completely or partially) fail to deliver the needs of some of the DSOs. This risk would reduce over time as DSO develop a better understanding of its future needs and, as a result, further harmonisation could be feasible in the medium to long term.
- Not all barriers have the same effect on the potential for harmonisation. Barriers caused by intrinsic characteristics of the electricity systems (i.e. characteristics that cannot be changed or that can be changed at a very high costs) could constitute barriers to harmonisation in the long term. However, barriers based on non-intrinsic features of the energy system (e.g. legislation) should not have the same relevance in this analysis as they could be modified if harmonisation is shown to be beneficial.

Using that framework, we found that when harmonising across SOs, products can be separated into two groups:

- frequency control – these products have a larger margin for harmonisation as potentially larger benefits could be achieved by harmonising between bidding zones as they do not require locational information. Furthermore, TSOs are the only users of these products and they have experience in using them which reduces the costs of harmonisation.
- Non-frequency control – for these products there is a smaller potential for harmonisation as they are location specific which means that the main rationale for harmonisation would be to facilitate the interactions between TSO-DSO-consumers by reducing the diversity between products. Furthermore, the potential barriers to harmonisation could also be higher as DSOs are only starting to use some of these products which, if harmonisation takes place, could result in harmonised products that do not always fit the actual needs of some of the DSOs.

This approach is consistent with the approach that is currently in use where frequency control products are being harmonised by the TSOs through a number of projects (e.g. PICASSO OR MARI). Once these efforts are already ongoing, in this project we will base our harmonised products on those being developed in those projects.

For non-frequency control products, we have implemented an approach where there is a certain degree of harmonisation that would facilitate the coordination between TSO-DSO-customers but without reaching a full harmonisation. In this approach, we have identified the list of attributes FSPs would need to identify to

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understand whether they can deliver the product while allowing certain variety among the values for some of these attributes. Furthermore, we have also identified products that, except for some different in the minimum size of the bids, could be used by both TSOs and DSOs once they have to address similar needs.

The harmonised products were then compared against the products being proposed by the demonstrators in this project. Among the demonstrators there is a focus on non-frequency control products, i.e. those products where they have less previous experience:

Table 9-1 Matching of product proposed by demonstrators against harmonised products

Demonstration	Proposed product	Harmonised product
Northern cluster	NRT- -P-E (Near Real Time Active Energy)	Corrective local active[19]
	ST-P-E (Short Term Active Energy)	Predictive short term local active
	LT-P-C/E (Long Term Active Capacity/Energy)	Predictive long-term local active
	ST-P-C (Short Term Active Capacity)	Predictive short term local active
	LT-Q-C (Long Term Reactive Capacity)	Predictive long-term local reactive
	NRT-Q-E (Near Real Time Reactive Energy)	Corrective local reactive, Predictive short term local reactive
Greece	Reactive support	Corrective local reactive
	Predictive congestion management for TSO/DSO product	Predictive short-term local active
	Power regulation mFRR	mFRR
	Power regulation RR	RR
	Severe state prevention/restoration product	Predictive long-term local active
Cyprus	Change of active power (i.e., load shifting, peak shaving)	Corrective local active
	Phase balancing	Corrective local active Corrective local reactive
	Change of reactive power (i.e., voltage regulation, reactive power compensation)	Corrective local reactive
	Active power rate of change capability (per minute)	aFRR
	Rapid active power change product according to system frequency	Inertia product
	Power regulation	mFRR
Portuguese	Products for Intraday Congestion Management for DSO/TSO	Predictive short-term local active
	Products for Day-Ahead Congestion Management for DSO/TSO	Predictive short-term local active
	Sustain	Predictive long-term local active

[19] When using as a frequency product, this product will be consistent with the use of mFRR.

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Demonstration	Proposed product	Harmonised product
	Secure	Predictive long-term local active
Spain	Day-ahead	Predictive short-term local active
	Real-Time	Corrective local active
	Agreed Activation Product	Predictive long-term local active
	Availability Product	Predictive long-term local active
France	Near real time corrective local active energy	Corrective local active product
Czech Republic	Local congestion management of active power	Predictive short-term local active
	Voltage Control by Q management / Reactive Power Management	Predictive long-term local reactive
Polish	Change in active power (+ & -) (CM + VC)	Predictive short-term local active
	mFRR	mFRR
	aFRR	aFRR
	RR	RR
Hungary	Change in active power (P) (CM & VC)	Predictive short-term local active
	Change in reactive power (Q) (CM & VC)	Predictive short-term local reactive
Slovenia	Congestion management and Voltage control via aggregator through a market platform	Corrective local active

These harmonised products were also compared against the products that TSOs and DSOs (inside of the project as well as outside) had identified as potential future products. This comparison shows that the harmonised products included all the relevant products identified by the different SOs. Furthermore, as part of that analysis it also became clear that both TSOs and DSOs are considering similar non-frequency products. Therefore, this would seem to confirm that harmonisation of the definition of the products between TSOs and DSOs could also facilitate their coordination as well as the FSP's investment decision-making as they would only need to identify one set of products instead of separate products for TSOs and DSOs. Furthermore, some of the demonstration partners are also considering using some of those products for multiple services which will help us to understand the potential for synergies to harmonise across services.

When considering harmonisation across services in this project, we have identified two potential approaches that could be followed in this harmonisation. In the first one of these approaches, one product is designed to ensure that it delivers all the services being considered (i.e. it is a superproduct). Therefore, when designing this product, the SO will set the values of the attributes and the FSP will be required to deliver all these values.

In the second approach, there is no product definition as FSPs can send offer that could address any of the needs of the regulator (i.e. the supermarket approach). In this case, it is for the SO to identify whether the flexibility being offered is able to address the needs it faces. Therefore, the SO will only set the information they require from the FSP and then optimise across the different bids.

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When considering these options, we found that both approaches have advantages and disadvantages and, as such, it is important to identify what are the main objectives to be achieved with the integration. Furthermore, it is possible that a hybrid option arises which allows a combination of superproducts that allow SOs to use some well-defined products for some of the needs while the supermarket approach is used to ensure that the SO can have access to the remaining flexibility.

Among the potential products harmonised across services, one has received some particular attention in this project: an mFRR products with a location component. This product could be used, at least, in the provision of frequency and congestion management services. Based on the discussion above, the product could be designed in two ways:

- FSPs need to provide location to participate in the market (i.e. those FSPs that can only put forward the product using units in more than one location could be excluded)
- FSPs could provide locational information if they want to be considered for non-frequency services.

The approach used for this definition could have important consequences on the overall performance of the market. For example, with the first approach, the SO operators knows that it can take the energy included in that product and use it for both services while for the second, the SO will first need to determine whether the bid is useable for its needs. Therefore, the first approach could reduce the liquidity in the market for this product while the second one would make the operations of the SO more complex.

At the outset it is not possible to determine which of these options is superior as its effects cannot be considered in isolation. For example, the effect of a superproduct can be very different depending on whether the rest of the needs are also served using superproducts (i.e. a share of the available flexibility could be unused as it is not able to deliver the requirements of a superproduct) or it is complemented by a supermarket (i.e. the additional flexibility could be traded in that supermarket which could increase the overall cost efficiency of the system).

With all that we find that the two extreme evolutions (full supermarket and one single superproduct) are unlikely to arise in practise. However, hybrid options could be considered to integrate all different sources of flexibility in the management of the energy system

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11 Appendixes

11.1 Matching of answers to harmonised products for State of the Art analysis

The current and future TSO products outlined in the State of the art (SOTA) assessment were mapped against corresponding scarcities such as frequency control (non-standardised), voltage control and congestion management as shown below in the table. It should be noted that some product(s) may cater to one or more scarcities.

Table 11-1 Products proposed by TSOs

Scarcity	Non-harmonised products identified in SOTA	Alignment with Products in the product framework
Adequacy		Capacity Renumeration
Frequency control	Inertia	Inertia
	Fast Frequency Response	Fast Frequency Response
	HPP (hydroelectric power plant) cascade	mFRR (standard)
	Drooping & Ramping Products	aFRR (Standard)
Congestion Management	Long-term active power capacity product (LT-P-C)	LT local active
	Short-term active power capacity product (ST-P-C) OR	ST local active
	Near-real time active power energy product (NRT-P-E)	NRT operational local active
	Real-time active power energy product (RT-P-E)	
Voltage Control	Reactive Power Availability (Inductive or Capacitive) OR UQ Control (Reactive Power)	LT local reactive
		ST local reactive
	Near-real-time reactive power energy product (NRT-Q-E)	NRT operational local reactive
	Real-time reactive power energy product (RT-Q-E)	
Black Start	Black Start Products	Black Start Products

Inertia, FFR, HPP Cascade (hydro assets connected in cascade for mFRR balancing energy), Drooping and Ramping products can all be categorized as frequency control products since the objective is to contain the

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frequency. As mentioned in Section 7.1, the level of inertia affects the frequency transient behaviour of grid (namely Rate of Change of Frequency, RoCoF) after active power imbalance. Specific technical requirements are required by the Inertia and FFR product given the unique service. Ramping product (linked to standard aFRR product) is expected to provide a certain amount of MW per minute (MW/min) for a certain time interval. Similarly, Drooping product (linked to standard aFRR product) is expected to provide a certain amount of MW according to the change of frequency from its nominal value (MW/Hz) for a certain time interval. It can be automatically activated when the flexibility resource detects a certain amount of frequency change.

When it comes to congestion management the products are expected to mitigate one or more constraints such as thermal limits, voltage limits, stability limits etc. which restrict the physical power flow through the network [21]. The most ideal approach to categorize products is to look at timeframes over which congestion management is required [47]. Here the long-term local active product may serve network reinforcement deferral or network support during planned maintenance (predictive phase). When the grid is pushed over its physical limits, the grid runs the risk of degradation e.g. accelerated depreciation of hardware or outage and resulting into malfunction. Here short-term local active products may be used preventively (predictive phase) to reduce the impact of outages, maintenance, or production patterns. NRT operational local active products can be activated after the occurrence of outage (corrective phase).

As the frequency is influenced by the behaviour of active power, the voltage is affected by reactive power. To maintain the grid voltages within required bandwidth, TSOs and DSOs should rely on reactive power supplied by local grid-connected assets [48]. Like congestion management the products for voltage control can be used in different timeframes (long-term, short-term, and near-real time) so that reactive power resources (e.g. shunt reactors, capacitor banks, generators etc.) can be reserved in the predictive phase and activated close to real-time (corrective phase).

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11.2 List of respondent DSOs

Cluster	Country	DSOs Analysed
Northern	Estonia	1
	Lithuania	1
	Latvia	1
Southern	Cyprus	1
	Greece	1
Western	Portugal	1
	Spain	2
	France	1
Eastern	Hungary	1
	Poland	1
	Czech Republic	2
	Slovenia	3
Not in the project	Austria	1
	Germany	1

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11.3 Questionnaire for TSOs

1 – Background information	
Name of the company	
Country of operation	
Activities undertaken by the company (e.g. TSO, DSO, SO)	
Name of the person answering	
E-mail	

2 – Service and product definition
To facilitate understanding, services and products are defined as:
a system service is defined as the action (generally undertaken by the network operator) which is needed to mitigate a technical scarcity or scarcities that otherwise would put the stability of the operations of the network at risk. **a product** is a tradable unit that the network operator acquires from flexibility providers and that entails the option to deliver a service in case of activation (this activation can be automatic if the product deals with the acquisition of energy). The characteristics of the technical scarcity mitigated by the relevant service will determine the attributes of the tradable unit.
What are the main system challenges that the company needs to address to ensure the stability of the network? *(multiple answers possible)*

Frequency control (balancing)	
Voltage control	
Rotor angle stability	
Network congestion management	
System restoration	
System adequacy	
Islanded operations	
Others	
If others, which ones?	

What are the products being considered / required for congestion management and voltage control? This would include both those products currently in use in the day-to-day management and those that are being considered as part of R&D efforts. As for frequency control, what are the products being consider outside of those being standardised in European projects (e.g. PICASSO, MARI, TERRE or IGCC) *[add lines as necessary]*

Name	Description

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3 – Detailed product analysis	
Please provide the values/ranges for each one of the attributes below (additional attributes can be added if required to have a clear definition of the product) for each one of the considered products? *[Please complete a full list for each product but leaving blank those attributes that do not need to be defined]*	
[Name of the product]	
Timing in the product	
Preparation period	*[Value is chosen for quantitative attributes /description for qualitative requirements]*
Start-up time	
Ramping period	
Full activation time	
Mode of activation	
Minimum/maximum duration of delivery period offer	
Deactivation period	
Recovery period	
Maximum number of activations (per day, week…)	
Choices for bid design	
Minimum/maximum bid size	
Divisibility allowed	
Direction of deviation (up/down)	
Granularity	
Certificate of origin	
Aggregation allowed	
Symmetric/asymmetric product	
Unit-based or portfolio-based within a certain geographical area allowed	
Minimum/maximum duration of delivery period requirements	
Characteristics of the traded good	
Capacity/energy	
Active/reactive energy	
Location	
Level of availability	
Pricing of the product	
Max./min Price	
Includes availability price	
Includes activation price	

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Other attributes [Please add lines as appropriate]	
Could this product be acquired from other network providers (e.g. other DSOs or TSOs)? If no, please describe the reasons why the product could not be traded.	*[Y/N]*
If yes, what are the attributes that would be considered to ensure that the product being acquired can be used?	
Other comments	

11.4 Questionnaire for DSOs

1 – Background information	
Name of the company	
Country of operation	
Activities undertaken by the company (e.g. TSO, DSO, SO)	
Number of connections	
Name of the person answering	
E-mail	
2 – Service and product definition	
To facilitate understanding, services and products are defined in the OneNet project as:	
a system service is defined as the action (generally undertaken by the network operator) which is needed to mitigate a technical scarcity or scarcities that otherwise would put the stability of the operations of the network at risk. **a product** is a tradable unit that the network operator acquires from flexibility providers and that entails the option to deliver a service in case of activation (this activation can be automatic if the product deals with the acquisition of energy). The characteristics of the technical scarcity mitigated by the relevant service will determine the attributes of the tradable unit.	
What are the products being considered / required for congestion management and voltage control? This would include both those products currently in use in the day-to-day management and those that are being considered as part of R&D efforts *[add lines as necessary]*	
Name	Description
Is there any other system challenge that your company is / will need to address going forward?	
Name	Description
If any system challenge is identified, what are the products being considered / required to address these additional scarcities?	
Name	Description
3 – Detailed product analysis	
Please provide the values/ranges for each one of the attributes below (additional attributes can be added if required to have a clear definition of the product) for each one of the considered products? *[Please complete a full list for each product but leaving blank those attributes that do not need to be defined]*	

[Name of the product]	
Timing in the product	
Preparation period	*[Value is chosen for quantitative attributes /description for qualitative requirements]*
Start-up time	
Ramping period	
Full activation time	
Mode of activation	
Minimum/maximum duration of delivery period offer	
Deactivation period	
Recovery period	
Maximum number of activations (per day, week…)	
Choices for bid design	
Minimum/maximum bid size	
Divisibility allowed	
Direction of deviation (up/down)	
Granularity	
Certificate of origin	
Aggregation allowed	
Symmetric/asymmetric product	
Unit-based or portfolio-based within a certain geographical area allowed	
Minimum/maximum duration of delivery period requirements	
Characteristics of the traded good	
Capacity/energy	
Active/reactive energy	
Location	
Level of availability	
Pricing of the product	
Max./min Price	
Includes availability price	
Includes activation price	
Other attributes [Please add lines as appropriate]	

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Could this product be acquired from other network providers (e.g. other DSOs or TSOs)? If no, please describe the reasons why the product could not be traded.	*[Y/N]*
If yes, what are the attributes that would be considered to ensure that the product being acquired can be used?	
Other comments	

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11.5 Questionnaire for demos (jointly for task 2.2 and 3.1)

	Background information				
Q. 1	Please provide your Name				
Q. 2	Please provide your Surname				
Q. 3	Please provide your Email address				
Q. 4	Which is your Organisation?				
Q. 5	Which is your Demo?				
Q. 6	Which is the Use Case name?		Q. 7	Use Case Starting date	
			Q. 8	Use Case Ending date	
Q. 9	What is the objective of the demo? [provide a brief explanation of the main objectives of this demo]				
Q. 10		TSO-TSO		Y/N	

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<table>
<tr><td rowspan="12"></td><td rowspan="12">What are the agents that the Demo is aiming to coordinate?
[e.g. TSO-DSO, TSO-TSO, DSO-DSO, DSO-FSP, other]:</td><td colspan="3">TSO-DSO</td><td colspan="3">Y/N</td></tr>
<tr><td colspan="3">TSO-FSP</td><td colspan="3">Y/N</td></tr>
<tr><td colspan="3">TSO-aggregator</td><td colspan="3">Y/N</td></tr>
<tr><td colspan="3">DSO-DSO</td><td colspan="3">Y/N</td></tr>
<tr><td colspan="3">DSO-FSP</td><td colspan="3">Y/N</td></tr>
<tr><td colspan="3">DSO-aggregator</td><td colspan="3">Y/N</td></tr>
<tr><td colspan="3">Peer-peer</td><td colspan="3">Y/N</td></tr>
<tr><td colspan="3">TSO-MO</td><td colspan="3">Y/N</td></tr>
<tr><td colspan="3">DSO-MO</td><td colspan="3">Y/N</td></tr>
<tr><td colspan="3">FSP-MO</td><td colspan="3">Y/N</td></tr>
<tr><td colspan="3">FSP-FSP</td><td colspan="3">Y/N</td></tr>
<tr><td colspan="3">other</td><td colspan="3">Y/N</td></tr>
<tr><td>Q. 11</td><td>Which voltage levels would be covered</td><td>High Voltage</td><td>Y/N</td><td>Medium Voltage</td><td>Y/N</td><td>Low Voltage</td><td>Y/N</td></tr>
<tr><td></td><td colspan="7">Service and product definition (Please indicate only one service per sheet)</td></tr>
<tr><td colspan="8">To facilitate understanding, services and products are defined as:</td></tr>
<tr><td colspan="8">A system service is defined as the action (generally undertaken by the network operator) which is needed to mitigate a technical scarcity or scarcities that otherwise would undermine network operation and may create stability risks.
A product is a tradable unit that the network operator acquires from flexibility providers and that entails the option to deliver a service in case of activation (this activation can be automatic if the product deals with the acquisition of energy). The characteristics of the technical scarcity mitigated by the relevant service will determine the attributes of the tradable unit.</td></tr>
<tr><td colspan="8"></td></tr>
</table>

Q. 12	Which service will be examined or are you considering examining?			
	Frequency control (balancing)	[Y/N]		
	Voltage control	[Y/N]		
	Rotor angle stability	[Y/N]		
	Network congestion management	[Y/N]		
	System restoration	[Y/N]		
	System adequacy	[Y/N]		
	Islanded operations	[Y/N]		
	Others	[Y/N]		
	If others, which ones?			

Q.13	What are the products being considered? *[add lines as necessary]*		
		Name	Description [including the service(s) that the product could provide in the demo and, when appropriate whether they align to any standardised product]
	Product 1		
	Product 2		

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Q.14	Please provide the values for each one of these attributed for each one of the considered products. *[Please complete a full list for each product but leaving blank those attributes that do not need to be defined] - [add columns as necessary]*				
	Product 1	**Product 2**	**Product 3**	**Product 4**	**Product 5**
Timing in the product	**Value chosen for quantitative attributes /description for qualitative requirements**	**Value chosen for quantitative attributes /description for qualitative requirements**	**Value chosen for quantitative attributes /description for qualitative requirements**	**Value chosen for quantitative attributes /description for qualitative requirements**	**Value chosen for quantitative attributes /description for qualitative requirements**
Product name					
Preparation period					
Start-up time					
Ramping period					
Full activation time					
Mode of activation					
Minimum/maximum duration of delivery period offer					
Deactivation period					
Recovery period					
Maximum number of activations (per day, week…)					
Choices for bid design					
Minimum/maximum bid size					
Divisibility allowed					
Direction of deviation (up/down)					
Granularity					

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Certificate of origin					
Aggregation allowed					
Symmetric/asymmetric product					
Unit-based or portfolio-based within a certain geographical area allowed					
Minimum/maximum duration of delivery period requirements					
Characteristics of the traded good					
Capacity/energy					
Active/reactive energy					
Location					
Level of availability					
Other attributes [Please add lines as appropriate]					
Could this product be used in the delivery of other service(s) by either DSOs or TSOs?					
Q.15					
Could this product be traded between the different members of the cluster? If no, please describe the reasons why the product could not be traded.					
Motivation:					

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If yes, which one of the attributes would be consider identifying whether the product can be used to satisfy the scarcity under consideration?					

Q.16	**Barriers to integration**				
Could this product be traded between the different members of the cluster? If no, please describe the reasons why the product could not be traded.	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*
Motivation:					
If yes, which one of the attributes would be consider identifying whether the product can be used to satisfy the scarcity under consideration?					

Q.17	Have these barriers affected the choice of products for the demos? If so, in what way?
Please answer here	
Q.18	**Other comments - Please provide general comments in case of additional clarification required**

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please answer here

	Features of the coordination model (Please indicate only one service per sheet)						
Q. 19	Does the Demo would define a new coordination scheme for TSO-DSO, DSO-MO, DSO-DSO coordination?	*[Y/N]*					
Q. 20	Which is the main motivation that would drive the coordination?						
Q. 21	Which would be the level of coordination?	Information sharing	Direct supervision	Standardised product	Standardised process	Standardisation in role interaction	*Other*
		[Y/N]	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*
Q. 22	Which would be the frequency of the coordination?	Single			Recurrent		
		[Y/N/?]			*[Y/N]*		
Q. 23	Which would be the phase of the coordination?	Prepare	Plan/forecast	Market phase	Monitoring and activation	Measurement, control of activation and settlement	*Other*
		[Y/N]	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*
Q. 24	Which would be the coordination fragmentation?	Centralized		Decentralized		Distributed (peer-to-peer)	

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		[Y/N]	[Y/N]	[Y/N]

Q. 25	Who would be the primary buyer of the flexibility?							
	Only TSO	[Y/N]						
	Only DSO	[Y/N]						
	Both TSO & DSO	[Y/N]						
	All TSO & DSO & Others (e.g. MO)	[Y/N]						
	Peers	[Y/N]						
	Only others (e.g. MO)	[Y/N]						
	If others, which ones?							
Q. 26	There would be a priority of access? If yes, please explain							
Q. 27	How many markets would be utilized or are considered to be used to buy flexibility?							
	• 1	[Y/N]						
	• ≥1	[Y/N]						
Q. 28	Does the TSO would have access to assets on the distribution level?							
Q. 29	In the case TSO and DSO can buy flexibility, does the TSO would be able to access to those offers submitted to the DSO but not used by him?							
Q. 30	Please, provide some explanation							

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		Procurement mechanisms (Please indicate only one service per sheet)							
Q. 31	What is the procurement mechanism under consideration considered for the service in the Use Case mentioned in Q. 12?	Considered?	Q. 32	Which are the procurement timeframes which would use or are likely to be used?					
			More than Annually	Annually	Weekly	Day-ahead	Intraday	Near to real time (15 min)	Other
	Flexible connection and access agreement	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*
	Dynamic distribution tariffs	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*
	Flexibility markets TSO	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*
	Flexibility markets DSO	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*
	Bilateral contracts	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*
	Cost-based	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*
	Other, please specify	*Not applicable*							
Q. 33	Is it under consideration an integration of the new market, if any, with the existing ones?	Service - Service		Energy - Energy				Service - Energy	
		[Y/N]		*[Y/N]*				*[Y/N]*	
Q. 34	If yes, please indicate with which ones? (e.g. day ahead, intraday, reserve)	*please answer here*							
Q. 35	Prices and schedules computed in the flexibility procurement mechanism (in Q. 31) would be able to modify those computed in previous markets?								

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Q. 36	If yes, please explain how this correlation is expect.	*please answer here*							
Q. 37	Which of the following processes would be considered or may be expected to be considered?	Resource registration & prequalification	Grid assessment	Bid collection	Market clearing	Metering	Baselining	Settlement	Other
			[Y/N]	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	*[Y/N]*	

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	Pricing (Related to the service under consideration indicated in Q. 12)	
Q. 38	Indicate the pricing methods which would be used or are taken into consideration for a possible use for pricing the considered service	
	Pay as cleared	*[Y/N]*
	Pays as bid	*[Y/N]*
	Dynamic tariffs	*[Y/N]*
	Discounts	*[Y/N]*
	Cost-based	*[Y/N]*
	Bilateral negotiated contract	*[Y/N]*
	If others, which ones?	*Not applicable*
	Geographical scope and network characteristics (Please indicate only one service per sheet)	
Q. 39	May the Demo involve the definition of procurement areas?	*[Y/N]*

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Q. 40	What would be the geographical scope and bidding areas for the mechanism adopted?					
Q. 41	It is expected a methodology to validate technically the flexibility offers?					
Q. 42	If yes, please indicate which of the following methods are likely to be considered for the service					
	Inclusion in the OPF	*[Y/N]*				
	Common regional AC power flow model	*[Y/N]*				
	Available Transfer Capacity	*[Y/N]*				
	Security constrained OPF (incl. cross-border flows)	*[Y/N]*				
	Others, please specify					
Q. 43	It may be considered a methodology for computing network sensitivities?					
Q. 44	Which would be the timing of grid constraints inclusion?	Prepare	Plan/forecast	Market phase	Monitoring and activation	*Other*
		[Yes/No]	*[Yes/No]*	*[Yes/No]*	*[Yes/No]*	

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	Flexibility service providers characteristics (Please indicate only one service per sheet)							
Q. 45	Are aggregators participating in the Demo?	*[Y/N]*						
Q. 46	For the service under analysis, please indicate what kind of resource provide are expected to provide the service.							
	Demand-side resources	*[Y/N]*						
	Storage	*[Y/N]*						
	Conventional generators	*[Y/N]*						
	Renewable generators	*[Y/N]*						
	Backup generators	*[Y/N]*						
	Facilities with both generation and consumption	*[Y/N]*						
	Electric Vehicles charging stations	*[Y/N]*						
	Others (please specify)							

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