Deliverable D6.7

Roadmap towards a new market design including the implementation of standardised products for system services

V1.0

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Executive Summary

A key societal challenge faced by the European Union (EU) is to ensure secure, clean, and efficient energy provision. The specific objective is to make the transition to a reliable, affordable, publicly accepted, sustainable, and competitive energy system, aiming at reducing fossil fuel dependency in the face of increasingly scarce resources, increasing energy needs, and climate change. Increasing Europe's share of renewable energy sources (RES) is also seen as a priority to reduce the regions dependence on energy imports and volatile fossil fuel supplies. The power grid is a key enabler in addressing these societal challenges and needs to keep up with the development of electrification and deployment of renewable intermittent energy sources.

This development result in some significant challenges. Some of these challenges and changes can, among other things, be solved through the provision of system services. System services are services provided to the distribution system operators (DSO) and/or to the transmission system operators (TSO) to keep the operation of the grid within acceptable limits for security of supply (1,2). These services and solutions necessitate greater coordination between the TSO, DSOs, and these new grid service providers as well as the end consumers offering their flexibility. The CoordiNet project is a response to this need for increased coordination and is funded by the Horizon 2020 programme. Over 42 months, in three European countries, valuable knowledge and experience have been gained.

This deliverable build upon the conclusions and results of the CoordiNet demonstrations which have been evaluated against four categories: regulatory, market, technological and social. This was done to identify recommendations to address potential barriers for the establishment and future scale-up and replication of the concepts tried out in the CoordiNet project. This analysis is here presented in the CoordiNet Roadmap, consisting of five themes describing the main building blocks of new flexibility markets, see Figure A. Under each theme, a set of recommendations have been formulated to adress identified barriers. In the following a summary of the prioritised recommendations is given.

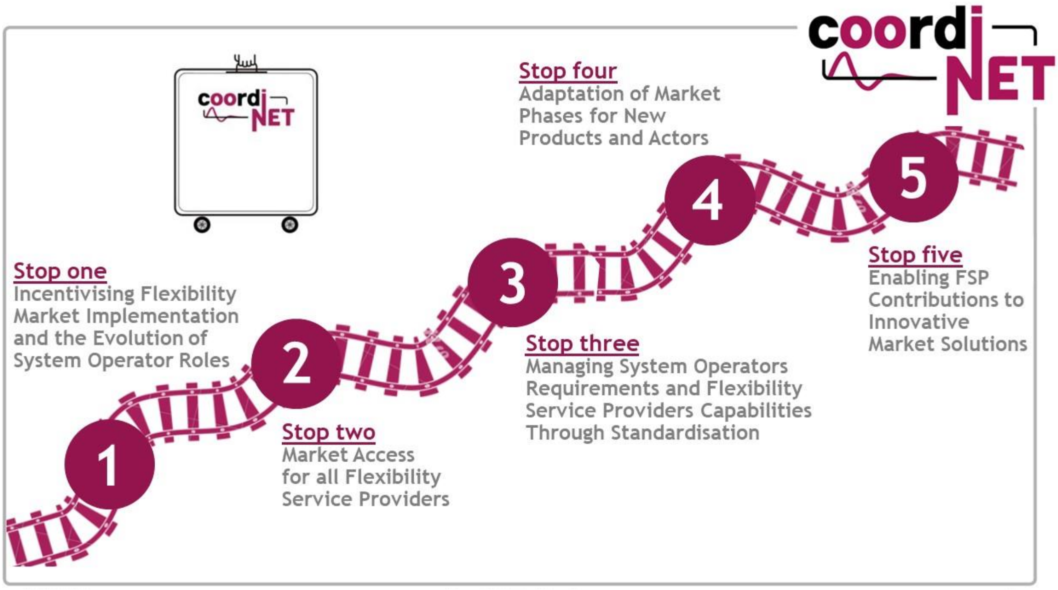

Figure A. The CoordiNet Roadmap, consisting of five themes describing the main building blocks of new flexibility markets.

1.1. Incentivising the evolution of SO roles and creation of flexibility markets

Across Europe the energy sector is in the middle of a re-structuring and modernisation process aimed to reach a unified energy market. During this re-structuring the interaction between TSO and DSO is expected to evolve for several reasons. With a higher share of DER connected to the distribution grid the role of the DSO should change and become more active to deal with new challenges. The electrification of loads and consumers along with increasing shares of DER connected to the distribution grids drives the need for SOs to implement flexibility solutions to utilise existing grids more efficiently. To ensure secure electricity delivery, the coordination between TSOs and DSOs will have to increase as the flows within the different levels of the system shift, moving from being strictly one directional with centralised production towards including increasing shares of DER and flexible energy consumers and storage units. To manage these new flows there is a need for SOs to develop new market solutions that would enable procurement of system services, as defined in the Clean Energy Package (CEP). However, the responsibilities and incentives for SOs to realise these solutions is not as clear.

1.1.1. Investment needs and economic incentives

The CoordiNet demonstrations highlight that current national economic regulation does not allow DSOs to recuperate their investments and costs for new market solutions for system services. To enable this, the cost of establishing these markets and mobilising flexibility must be recognised in DSOs remuneration schemes. In addition, the benefits of flexibility solutions have society-wide effects and public institutions could play a more active role in promoting both flexibility and efficiency solutions.

1.1.2. Roles and responsibilities

CoordiNet recommend to define clear roles and responsibilities in new established flexibility markets including both actual and new agents involved in these processes. To support this, a common EU-level definition of roles and responsibilities should be included in the new network codes for the distribution level. Especially for DSOs, flexibility markets will require a different approach to planning their operations. To enable DSOs to work proactively and complement current near real-time operational practices, with longer procurement horizons, national regulatory authorities should also take into consideration procurement of flexibility, to mitigate structural congestion, in the Network Development Plan.

1.1.3. Increased SO coordination

The implications of new resources connected to both TSO and DSO networks have to be properly accounted for as well as the impact of demand growth which may affect the reinforcement requirements of networks. However, if grid planning is done in a coordinated manner, reinforcement needs may actually be reduced for both grid operators with the implementation of flexibility markets. Higher coordination will help limit any negative effect and consequence of flexibility procurement on other voltage levels and in the long-term enable flexibility markets to scale up. In addition, higher coordination will result in maximising the overall efficiency of service procurement.

1.1.4. Market design and coordination schemes

To establish liquidity and attract FSPs in the early stage of development of flexibility markets, simple market coordination schemes are recommended. With time, a more complex approach should be explored, where both DSO and TSO have access to the same markets and resources, as it could result in more efficient market optimisation. Coordination schemes that allows for a common pool of flexibility resources for SOs would result in higher complexity but would enable the maximisation of social welfare, i.e. the maximising of surplus for both buyers and sellers, as the offered flexibility can concurrently serve the needs of multiple SOs and increase overall market liquidity.

1.2. Market access for all flexibility service providers

Improving TSO-DSO-consumer cooperation, and the development of platforms to enable this, has been one of the main goals for the project with the ambition to support long-term aims to allow all market participants to provide energy services. The previously one-directional electricity supply is becoming more dynamic and flows of electricity are changing as new grid service providers are emerging. Awareness is growing of the need for large-scale integration of RES and electrification to reach climate targets, and the consumers role in the value creation process is becoming more evident and present in the public debate.

Establishing flexibility markets would open new revenue streams and benefits for consumers providing system services. However, to achieve system level impact, substantial flexibility volumes and capacity from these new market actors, flexibility service providers (FSPs), will be necessary to meet the growing demand for flexibility. However, barriers exist for developing a convincing business case for FSPs as regulations and markets are currently set up to support traditional functions and actors.

1.2.1. Viability of the flexibility service provision business case

Currently, high costs for FSPs to manage their market participation reduces their margins of profit significantly. FSPs participating in the CoordiNet demonstrations suggested that support for higher degrees of automation could help increase participation in the markets and reduce time spent to manage market particiaption. Likewise, insecurities regarding return on investment for market participation is exacerbated by the differences in flexibility demand between seasons/year-to-year. This variability makes it difficult to attract FSPs as their supply would create profits with high variability across time. In the CoordiNet demonstrations clear communication, from SOs on how much flexibility is needed and when it will be needed, was implemented to help mitigate insecurities caused by the variability of demand. To further reduce the economic uncertainties and provide a higher degree of predictability of income regarding the potential business case of FSPs, market prices must accurately and transparently represent the value of the service which is affected by the location of the resources in the grid and its availability in time. The procurement of availability products is especially highlighted by the FSPs in the demontrations as a key for their participation and to assure viability of their business case.

1.2.2. Ensuring access and setting transparent rules for participation for all market actors

For all potential service providers to access these markets, thereby securing the necessary volume of flexibility, regulatory overview will be necessary as the scalability and replicability analysis of the CoordiNet demonstrations showed, regulatory barriers are still significant for DERs, of a broader span of sizes and technologies, to participate in the markets tested in the project.

1.2.3. The independent aggregator

For small-scale resources to cope with the technical requirements of markets, one solution is aggregation. The concept of independent aggregation is formalized in the CEP, but full implementation is taking time, hampering the participation of this actor. The aggregator should be able to participate in flexibility markets on the same terms as all other FSPs and the implementation of the CEP in national law should be facilitated to increase the viability of the aggregator business model, allowing for overall increased liquidity. Implementation of rules for how this actor can interact in the markets should be a priority in all Member

States. For example, it is not defined how the effects of the independent aggregator's market activities, on energy suppliers and balancing responsible parties, should be corrected and each Member State could implement different approaches.

1.2.4. Consumer awareness and perceptions

Currently, there is low level of awareness and understanding of grid related issues and potentials for flexibility service provision. Providing clear and reliable information for FSPs on how to access markets via user friendly and well-designed platforms and interfaces will be important to bridge information gaps on market opportunities. Clear and transparent provision of information regarding potential for market participation will be important to help new market participants and utility customers understand their electricity consumption profile and what their flexibility is worth across markets and across time. For many FSPs participating in the CoordiNet demonstrations the trials provided an important and valuable learning opportunity which will continue to add value to future market implementations. Providing opportunities for learning will be important to lower the threshold for participation, especially for those actors where flexibility provision lies far away from their core business.

1.3. Managing SO requirements and FSP capabilities through standardisation

Setting the right level of standards and rules is key to allow for continued innovation and testing of new solutions while at the same time creating a clear and well-defined framework that reduces complexity of participation. In such standards the already discussed requirements and highly regulated environment of DSOs and TSOs must be balanced with the capabilities of new market actors. Striking this balance will be important in order to replicate the CoordiNet demonstrations at multiple sites and support long-term attempts to scale up at EU-level and integrate with other already established markets. To be able to strike this balance a distinction has been made between harmonisation and standardisation, where standardisation is considered more absolute, and attributes are defined using one single value. Harmonisation is considered less confining in the sense that it aims to reduce variations without aiming to achieve one common value per attribute across an entire market.

Beyond the specifics of products there are a significant amount of flexibility market rules and frameworks that need to be amended or implemented. It will be crucial to ensure that regulatory and market set ups, implemented for the current market regime, are adapted to accommodate new actors and new functions. Validation of service delivery, grouping of assets, power of attorney ensuring access to data and control of flexible resources by the DSO, protocols for communication, and frameworks for data exchange and security are just some of the aspects that must be considered for standardisation processes.

1.3.1. EU-level standardisation of flexibility markets

Firstly, alignment of flexibility products, to avoid further proliferation of product formulations, will be necessary to ensure efficient allocation of flexibility and reduced complexity. However, what is evident in the CoordiNet demonstrations, is that the highly localised application of both congestion management and voltage control will need more trials and research before definitions for product values or ranges will be advisable. Firstly, for these services, harmonisation of common attributes is advised but strict standardisation of values is not advisable. In addition, different terminology is used in Member States within flexibility markets services which easily create misunderstandings and errors. To be able to harmonise processes and further along the market products an agreement on terminology will be needed. The common attributes applied within CoordiNet are seen in Figure B. For balancing products high level of harmonisation across the EU is already achieved with standards set within Member States. To ensure market access for new actors, these standards should be reviewed.

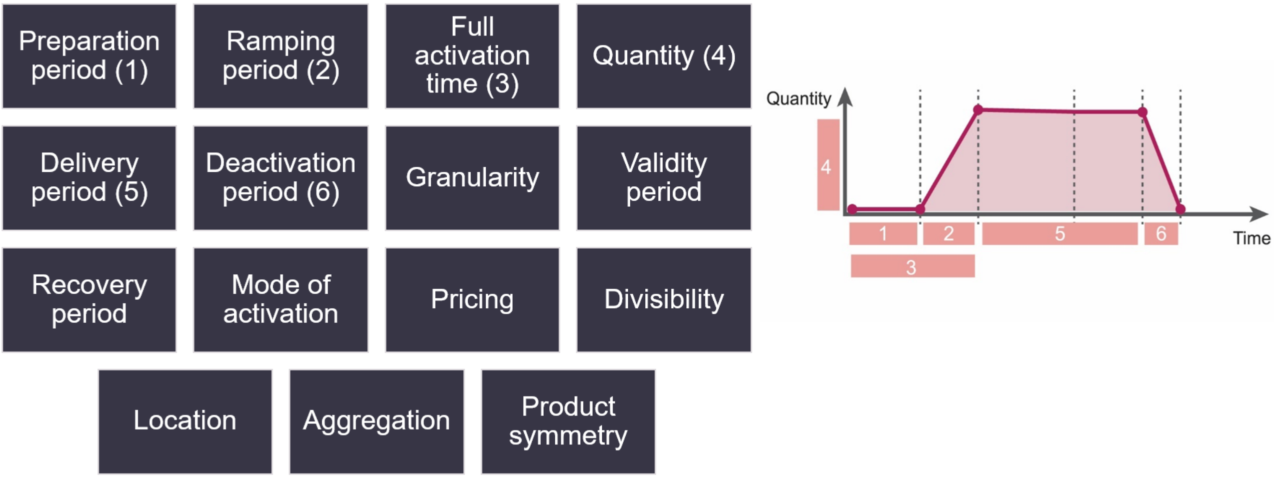

Figure B. The common list of attributes is suggested to contain the parameters included in the illustration. The numbers connected to the attributes responds to the schematic of a product description (right). Illustration sourced from CoordiNet deliverable D1.3, adapted from (14).

Secondly, it is of high importance to develop principles for the product prequalification (25). The CoordiNet demonstrations have, throughout the project, found that processes for prequalification would greatly benefit from standardisation to reduce market complexity and lower market entry barriers. The CoordiNet experience has led to the recommendation to carry out regulatory harmonisation to remove barriers that could impact open competition, efficiency, and non-distortion as well as implement general frameworks and principles for these where they are missing.

1.3.2. Setting standards and requirements for data flows and platform interoperability

To enable an efficient and well-functioning market, the Coordinet demonstrations all found that standardised processes for collecting measurement data and interoperability is necessary, both between grid components and market platforms. Currently, there is no common European framework to ensure interoperability between flexibility market platforms. If several separate markets exist, different interfaces and market procedures increase complexity, ICT costs, and need for IT-security measures. However, such investments in ICT and IT-security will be unavoidable as development of data exchange systems, as well as the standardisation of systems, protocols, and data formats, is necessary regardless of market design. The costs of implementation will though vary between Member States and could be reduced with standardised processes and ensured interoperability where needed. In the CoordiNet demonstrations, the selection of protocols and technologies for ICT were in many cases forced due to technical reasons or legacy systems. Harmonisation of rules and requirements will be important to promote an environment where choices are guided by best practice and can support an efficient and secure electricity systems. The development and implementation of electricity market data exchange standards would be an advantage that could facilitate the deployment and maintenance of market platforms and communication tools.

When interviewed, participating FSPs mentioned that standards for market messages, metering data, and baseline provision where areas that would benefit from standardisation to reduce the complexity of market participation. Currently, there is no general agreement at European level on minimum data requirements for flexibility services and what data can be provided on aggregated level or not by FSPs to SOs. Here it becomes important to stress that deployment of smart meters is a prerequisite for proper function of markets. However, as detailed in the draft Framework Guideline on Demand Response put forth by ACER, in countries or regions where smart meter deployment is delayed, rules in Member States must be in place that specify the conditions for the usage of sub-meters.

1.4. Adaptation of market phases for new products and actors

The development of new flexibility markets will result in new challenges in all market phases; prequalification, procurement and activation, and settlement, to adapt to new market participants and roles. In addition, CoordiNet has highlighted the fact that the efficiency of the coordination schemes can be directly affected by entry barriers and differing requirements and product specifications between markets, when those occur. Hence, different coordination schemes may become more or less adequate in different instances depending on the prevalent practical settings such as, national grid characteristics, the design of the flexibility products and their specifications, and entrance costs to the markets. Beyond the aspect of coordination schemes as well as market timing, the market phases detailed in the CoordiNet Roadmap are prequalification, procurement and activation, and settlement.

1.4.1. Timing aspects and integration of new flexibility markets

Setting flexibility market timeframes will have an impact on the activity of FSPs, i.e., market participants who have for instance large uncertainties when it comes to unit commitment. These actors would prefer shorter planning horizons. At the same time, when the utilisation of multiple markets is coordinated as a sequence of market windows, forwarding of bids could be realized which might affect, the economic attractiveness of the flexibility market but also the liquidity in all connected markets. From the SOs perspective the timing of market closure affects the time used for evaluation of grid status, also taking into account results from earlier energy market sessions. Efforts should be put on integrating flexibility markets with already established markets and processes to not disrupt these, as well as making sure to minimise complexity for FSPs to participate. The coordination between markets will be important to avoid overlapping which risks loss of liquidity. However, CoordiNet do not recommend standardisation of market timing on EU level as it depends on national and local context.

1.4.2. Prequalification

Harmonisation of requirements and processes for prequalification is desired across flexibility services and market platforms to increase liquidity and reduce complexity. CoordiNet highlight that, processes should be automatised to the largest extent possible. In addition, prequalifying for a service with more strict requirements could entail automatic qualification for services with less strict requirements to avoid duplicating processes. The demonstrations also highlight that other aspects, besides product requirements, should be included in the prequalification process, such as testing the communications between the FSP and the market platform.

1.4.3. Procurement and activation

Key factors impacting the implementation of flexibility markets in regard to procurement and activation are strongly linked to the quality and accuracy of grid representation in the market. Usually, the location or spatial dimension of the flexibility provider is not very important for frequency-based products, as long as it is within the relevant control area and fulfils the technical pre-qualifications. However, the location of the flexibility provider is an essential factor for congestion management and voltage control. As a result, the optimal use of the offered flexibility in flexibility markets requires a critical assessment of network constraints and resource location needs. Insufficient grid representation in the market could thus impact pricing (due to sub-optimal bid selection) and lead to a violation of network constraints, if matching, of where in the grid issues have occurred and the location of the most appropriate flexibility resource, is not taken into account in the bid purchasing process.

1.4.4. Settlement

How to best ensure that fair compensation is given based on activation and provision of service to the grid is a key factor for the establishment of a successful market. Currently, low observability in low voltage grids, due to lack of smart- and sub-metering data, will make accurate settlement processes difficult to achieve. The settlement process requires monitoring of several grid parameters and collection of their real-time telemetry measurements or calculated values, with the necessary granularity and frequency depending on the flexibility service in consideration, as well as baseline provision from FSPs.

As both the baseline as well as measurement data is the foundation for verification of delivery, settlement, and subsequent payment for the delivered flexibility, transparency is very important. Lack of measurement data transparency can result in gaming as it becomes difficult to verify the delivery of procured flexibility from a specific market participant. Measures should be taken to ensure transparency in data exchanges necessary for settlement processes in flexibility markets to increase trust among all stakeholders. In some cases, this might call for an independent third-party performing this process, which could be subject to external auditing.

1.5. Enabling FSP contributions to innovative market solutions

In this theme two developments within system service provision, that are still in a very early state of testing, is explored. Due to their early stage of development, flexibility system services for reactive power and by use of peer-2-peer markets could not be included in the CoordiNet demonstrations at the same level of detail as active power and traditional energy market concepts. Thus, potential recommendations valid for flexibility market concepts that have developed further will be less applicable for these two trials. In the following we will therefore discuss the findings from reactive power and peer-2-peer (P2P) markets demonstrations in isolation to give recommendations adapted to the readiness level of these concepts.

1.5.1. Markets and products for reactive power

Reactive power can neither be transported over long electric distances nor across several voltage levels. Therefore, reactive power must be provided by local assets on an appropriate voltage level. The farther away the asset lies within the system, the less effective. The organisation of any large-scale market is therefore complicated. In addition, as reactive power in many Member States is provided by mandatory connections and by SO owned assetts, it is not as straight-forward to implement a market solution as it is for congestion management for example. These innate characteristics result in barriers for a strict market-based approach of procurement and should therefore be enabled to co-exist with a rules-based approach. The efficiency of both approaches will vary depending on the context and thus need to ensure the ability of SOs to choose the most efficient solution in each case. It is therefore recommended to implement regulatory sandboxes where this system service and the favourable conditions for its adaptation within a market-based approach to flexible system service provision can be further explored.

1.5.2. Peer-2-peer markets for system services

P2P trading is the buying and selling of energy between two or more grid-connected parties and this concept has emerged as an alternative for prosumers to actively participate in the energy market. However, few projects focus on the establishment of P2P markets for explicit system services delivery on the request of the DSO/TSO which has been the focus of the CoordiNet project. The CoordiNet demonstration focused on large-scale actors and trading was implemented at fixed and planned periods where curtailment of renewable energy sources would otherwise be necessary instead of in a continuous market with many small-scale actors. The demonstrations showed great potential in allowing for more efficient use of already existing grid infrastructure as well as avoidance of renewable energy curtailment. The scale of the test was however not sufficient to draw any strong conclusions. As with market-based solutions for reactive power, CoordiNet recommends the creation of regulatory sandboxes to assess the benefits and impacts of P2P seeing as these are still largely unknown. The potential for incentivisation mechanisms for market establishment should also be further explored to discern whether or not investment in market implementation and participation can be retrieved through the economic benefits of P2P markets for system services.

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Abbreviations and acronyms

Acronym/Abbreviation	Description
ACER	Agency for the Cooperation of Energy Regulators
BRP	Balancing Responsible Parties
BUC	Business Use Case
CACM	Capacity Allocation and Congestion Management
CEP	Clean Energy Package
CGMES	Common Grid Model Exchange Standard
CIM	Common Information Model
CLC	Capacity Limitation Services
DA	Day-Ahead
DCC	Demand Connection Code
DEA	Data Envelopment Analysis
DER	Distributed Energy Resources
DSO	Distribution System Operator
EBGL	Electricity Balancing Guideline
EC	European Commission
EoEB	Exchange of Energy Blocks
EP	European Parliament
EU	European Union
EV	Electric Vehicles
FCR	Frequency Containment Reserve
FSP	Flexibility Service Provider
GDPR	General Data Protection Regulation
GL	GuideLines
HERM	Harmonised Electricity Market Role Model
HV	High-Voltage
ICT	Information and Communications Technology

1. The new context for the electricity grid

A key societal challenge faced by the European Union (EU) is to ensure secure, clean, and efficient energy provision.[1] The specific objective is to make the transition to a reliable, affordable, publicly accepted, sustainable, and competitive energy system, aiming at reducing fossil fuel dependency in the face of increasingly scarce resources, increasing energy needs, and climate change. Increasing Europe's share of renewable energy sources (RES) is also seen as a priority to reduce the regions dependence on energy imports and volatile fossil fuel supplies. REPowerEU is the European Commission's (EC) plan to, among other strategies for increasing the energy systems' resilience, rapidly accelerate the clean energy transition and the inclusion of larger shares of RES in Europe's electricity supply (3). Achieving these objectives will require an overhaul of the energy system combining low carbon profiles, the development of alternatives to fossil fuels, safeguarding energy security and affordability, while at the same time reinforcing Europe's economic competitiveness.

The historically, relatively, predictable development of electricity demand coupled with large scale plannable power provision has resulted in a stable and one directional relationship between electricity production, grid operation, and the final consumer. However, the power grid is a key enabler in addressing these societal challenges and needs to keep up with the development of electrification and deployment of renewable intermittent energy sources. High levels of variable renewable generation lead to a shift from traditionally synchronous generating units to non-synchronous technologies and more unpredictable energy supply. This leads to technical challenges, scarcities and flexibility needs (4), and shifts in the functional foundation of the power system where the previously predictable and plannable operation will go through significant changes.

Some of these challenges and changes can, among other things, be solved through the provision of system services. System services are services provided to the distribution system operators (DSO) and/or to the transmission system operators (TSO) to keep the operation of the grid within acceptable limits for security of supply (1,2). These services and solutions necessitate greater coordination between the TSO, DSOs, and these new grid service providers as well as the end consumers offering their flexibility. The CoordiNet project is a response to this need for increased coordination and is funded by the Horizon 2020 programme. Over 42 months, in three European countries, valuable knowledge and experience have been gained. The assessment of the results and conclusion drawn from the project is here presented in the CoordiNet Roadmap.

1.1. The CoordiNet Project

The CoordiNet project was a response to the call LC-SC3-ES-5-2018-2020, entitled "TSO – DSO – Consumer: Large-scale demonstrations of innovative system services through demand response, storage, and small-scale generation" of the Horizon 2020 programme. The project aimed at demonstrating how DSO and TSO shall act in a coordinated manner to procure and activate system services in the most reliable and efficient way through the implementation of three large-scale demonstrations. The CoordiNet project centred around three key objectives (Figure 1):

[1] https://cordis.europa.eu/programme/id/H2020-EU.3.3.

1. To demonstrate to which extent coordination between TSO/DSO will lead to a cheaper, more reliable, and more environmentally friendly electricity supply to the consumers through the implementation of three large-scale demonstrations, in cooperation with market participants.
2. To define and test a set of standardised products and related key parameters for system services, including the reservation and activation process for the use of the assets and finally the settlement process.
3. To specify and develop a TSO-DSO-Consumers cooperation platform starting with the necessary building blocks for the demonstration sites. These components will pave the way for the interoperable development of a pan-European market that will allow all market participants to provide energy services and opens new revenue streams for consumers providing system services.

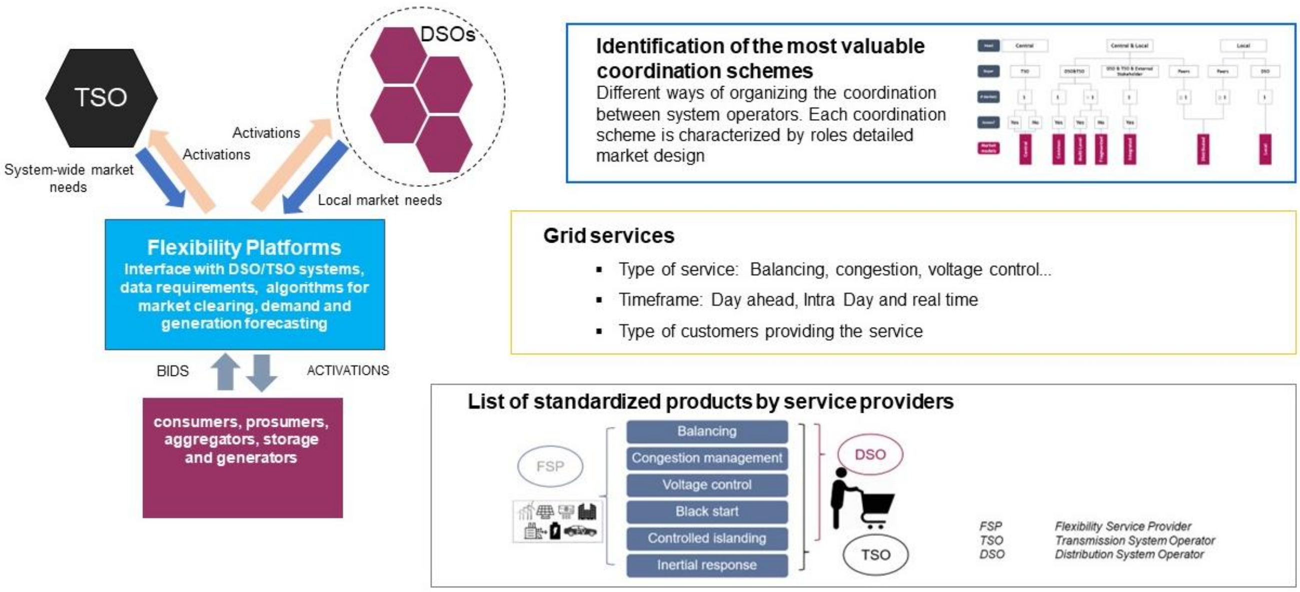


Figure 1. Illustration of the CoordiNet approach and key objectives.

In total, eight demonstration activities were carried out in three different countries, namely Greece, Spain, and Sweden. In each demonstration activity, different products were tested, in different periods of time, relying on the provision of flexibility by different types of Distributed Energy Resources (DER).

1.2. Goal and Scope of the CoordiNet Roadmap

The objective of the CoordiNet Roadmap is to summarise findings from the project consortium by presenting necessary actions for implementation and providing recommendations for an adapted market design at EU level. For the demonstration countries, more detailed findings that are highly context-dependent are presented as *Insights from the demos*. Given the variations between Member States and what was possible to test in the different demonstration sites, some results will be applicable to a varying degree for different countries. The overarching recommendations presented in this Roadmap are, however, developed to allow for broader and more generalised application. The resulting Roadmap outlines the steps needed to transition the current market design to one that allows for higher levels of flexibility, enables a more reliable and environmentally friendly electricity supply, and increases the coordination and cooperation between stakeholders.

Please note that reactive power products and peer-2-peer (P2P) markets could not be included in the CoordiNet Roadmap at the same level of detail as active power and traditional energy market concepts since they are still rather in early development stages. Voltage markets for DERs (including markets for reactive power) are still in the developing phase and have yet to reach a technology readiness level beyond 5, out of possible 9 (5). P2P markets have, according to the same evaluation criteria, been awarded a higher readiness level of 7 (6). However, this rating was garnered as a part of the overall umbrella of "local energy trading". The specific P2P concept tested in the CoordiNet demonstrations differs from the traditional P2P pilots as within CoordiNet we focus on P2P trading in the context of system services and have been tested at smaller scale in the demonstrations. Thus, reactive power products for voltage control and P2P markets are therefore treated in a separate section of the Roadmap. The CoordiNet demonstrations have focused on the service of controlled islanding to a limited extent and findings for this service is only reflected in results presented in section 4.3.1.5.

1.3. Structure of the Report

In the following chapter the methodology for developing the CoordiNet Roadmap is presented. Background information and context is given in Chapter 3 for the main concepts discussed in the deliverable. The results of the CoordiNet demonstrations, the analysis carried out within the project, and recommendations for enabling implementation of tested solutions are presented in Chapter 4. The final conclusions from the CoordiNet project also led to suggestion of additional studies and next steps on the way towards a flexible power system, which are presented in Chapter 5.

2. Analytical and Methodological Approach

Historical technological transitions have mostly been of an emergent nature where technological developments and leaps have driven transitions and changes in society. Global goals for decarbonisation set an unprecedented task for society where the technological transition and development of the electrical grid is driven by a pre-defined target which demands concerted action and collaboration between a multitude of stakeholders and sectors. Such a transition requires complex negotiations and management of trade-offs between actors involved and several topics of interest must be considered. To complement the large-scale demonstration activities, where technological solutions and business use cases (BUC) have been tested in practice, the analytical approach to develop the CoordiNet Roadmap takes into consideration a broader context. A multitude of processes need to be aligned for the "big picture" to fall into place. The application of the proposed multi-level-perspective, as presented in Figure 2, entails looking at how niche innovations, tested in the CoordiNet project, can be implemented into the regimes that currently shape the power system. The implementation of flexibility markets is framed by several overarching transition drivers, which shape the landscape where this solution is implemented, both on an EU-level, to provide cheap clean energy for all its citizens, and on a global level to meet climate targets.

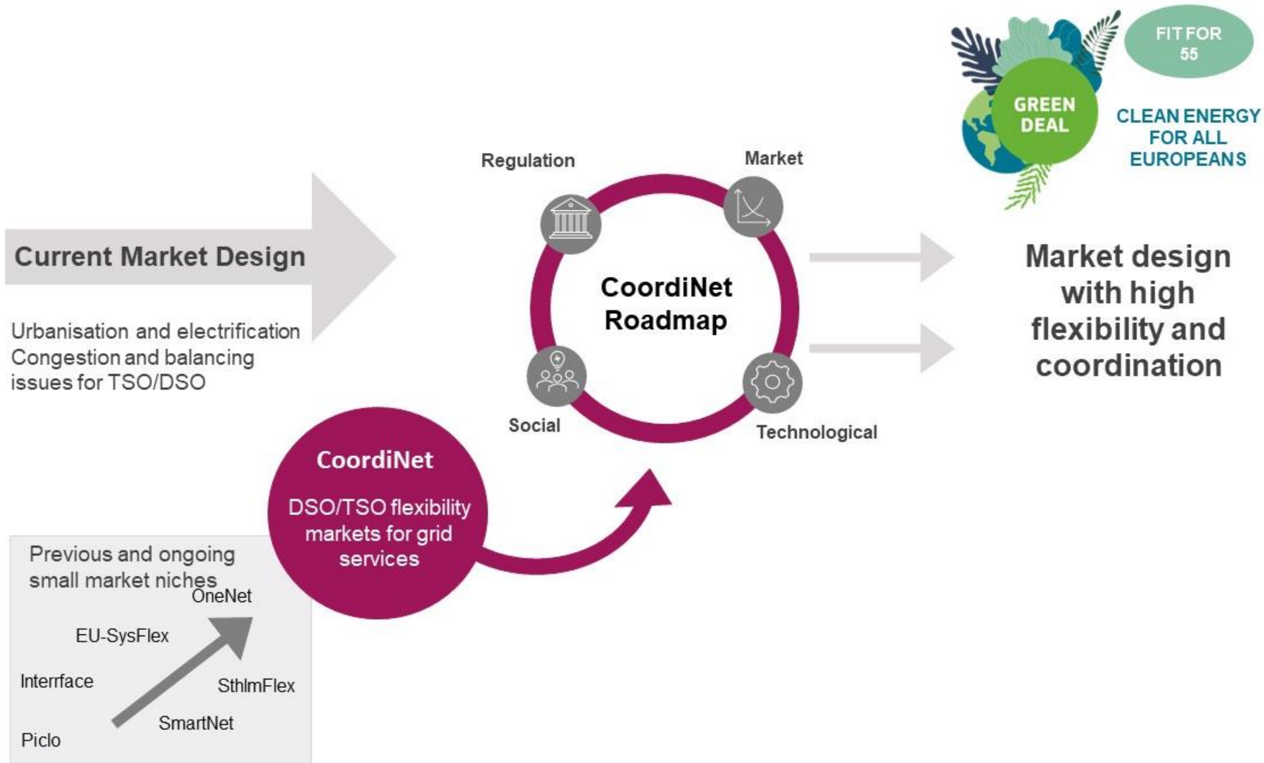


Figure 2. Multi-level perspective used as framework to develop the CoordiNet Roadmap. Own illustration adapted from Geels & Schot's multi-level perspective on sociotechnical transitions (7).

2.1. Methodological approach for developing the roadmap

The CoordiNet Roadmap is developed in four steps, outlined in Figure 3. In step one, adapted from the process used in the deliverable D6.2 of the SmartNet project (8), the most important requirements and conditions for market design, derived from previous project activities and initial results, are discussed and thematic topics are defined. In step two, these topics are applied to a literature review on the EU regulatory framework and other relevant documents to identify potential barriers for implementation. In the third step, the first outline of the roadmap is constructed. Solutions and recommendations to address identified barriers for implementations are defined. The fourth step focuses on interacting and iterating with the stakeholders to further refine the developed roadmap. In this final step further interviews as well as surveys are carried out to evaluate the roadmap's efficacy and saliency.

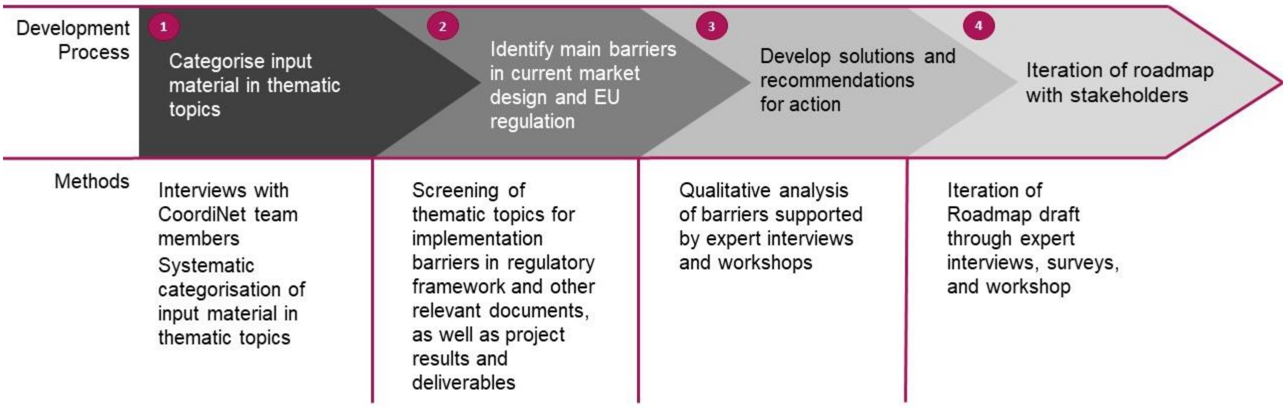


Figure 3. The four-step methodological process to develop the CoordiNet Roadmap.

2.1.1. Step 1: Categorise main conclusions and results in thematic topics

To initiate the screening process, thematic topics are determined to describe the characteristics of the market solutions tried out in the demonstrations, as well as to reflect the goals and aims of these. The topics of interest, listed in Table 1, are defined by the experts participating in the project, assembled through internal workshops and brainstorming sessions, with continuous input from the demonstrations, and other project partners. Naturally, these topics capture the main building blocks of energy market design. Topics include: the different market actors and the division of roles and responsibilities, the design of products for new flexibility markets and their level of standardisation, the overall market design and market phases (prequalification, procurement and activation and settlement), as well as what is needed by the market actors in terms of decision support tools, accurate baselines, and geographical scope of and network representation in the markets. As outlined in section 1.2, markets for reactive power products for voltage control and P2P markets concepts are still in early development stages. Hence, they are threated separately from the active power concepts and markets.

Table 1. Table of topics used to evaluate project results to identify barriers, as well as perform a complementary literature screening.

Thematic topics for results evaluation	
Roles and responsibilities	Level of product standardisation
Requirements for information sharing	Procurement of capacity vs energy
Common vs separate markets	Requirements of prequalification process
Grid decision support tools	Market clearing, bid selection, and pricing
Aggregation	Geographical scope and network representation
Market timing aspects	Requirements of settlement process
Enabling customer engagement	Markets and products for reactive power
Baseline methodology	P2P markets for system services

2.1.2. Step 2: Identify main barriers in current market design and EU regulation

In the second step of the development of the CoordiNet Roadmap, the topics list is used as a basis to categorise and review previous project deliverables and search for complementary literature. The exercise is focused on finding barriers within the institutional and regulatory ambit, that could have market, technological, and social effects.

Relevant organisations[2] issuing policy papers and regulatory relevant studies to include in the analysis were in this process identified, mainly by looking closer into documents which treated expected changes in energy markets or the emergence of new markets, as well as documents regarding already established wholesale and balancing markets. The documents included also cover regulatory documents for the current market design as well as EU directives of importance for the energy sector. The selected documents that were part of this review are listed in Appendix A. Additional literature and results from the research field were added to the literature review from previous and ongoing small market niches in the field of flexibility markets. From this start set of literature, backward snowballing searches allowed for an iterative approach to complement the start set literature (9).

The screening is done by identifying relevant questions to each topic on the list, see Appendix B, to be able to evaluate and find relevant information when screening the selected documents, focusing on barriers for implementation of flexibility markets. Also, aspects of integration with current markets and future development of the energy system are taken into consideration. The results from the literature screening are analysed from several perspectives in accordance with the framework presented above. In parallel, in-depth interviews with the three CoordiNet demonstrations are performed to evaluate which barriers were found within the project as a whole and categorise them in accordance with the identified topics list (Table 1). In this way findings are cross validated between the CoordiNet project and literature screening which helps to identify main barriers within current market design and regulation.

2.1.3. Step 3: Development of solutions and recommendations for actions

In step 3, the analysed results from the demonstration activities and project analyses, together with the literature screening, are qualitatively evaluated. The barriers identified in step 2 are evaluated and clustered in relevant themes that will be the base of the roadmap. This qualitative analysis is made within the CoordiNet consortium based on input from the partners of the project to establish a correct set of clusters that represents and highlights the results of the project. This process is iterated various times within the working group to ensure a salient structure is found.

Based upon the identified clusters of barriers, an internal workshop was performed including the project partners of WP 6, the demonstration leaders, as well as other relevant partners of the consortium. The purpose of the workshop was to finetune the grouping of barriers and perform a prioritisation of the barriers through a risk evaluation, ordering the barriers according to a scale of likelihood and impact, establishing the level of urgency of each barrier. Based on this evaluation and qualitative analysis of the material, solutions and high-level recommendations for implementation are developed, resulting in a list of actions. For each proposed recommendation potential impacts on current markets and market actors, need for

[2] Organisations screened for relevant documents were for example governmental organisations, regulatory associations, and industry associations.

technical standardisations and digitalisation, economic impacts, and potential synergies with other initiatives were considered.

2.1.4. Step 4: Iteration of roadmap with stakeholders

In step 4, that is done in parallel to step 3, the resulting list of recommendations and actions for implementation is used to continuously iterate the roadmap with external stakeholders. A selected group of key stakeholders is invited to review the roadmap through iteration activities. The iteration activities included are an overarching questionnaire in connection to an interactive presentation, open for all stakeholders (Appendix C). An additional more detailed questionnaire is also sent out, focusing on policy groups and TSO and DSO organisations. The result of this questionnaire is also used to produce an additional policy brief published in addition to this deliverable. Lastly, in-depth interviews are performed with key stakeholders, including policy makers on EU-level, business organisations and interest groups (Appendix C). A set of questions following the roadmap structure were prepared and used in both for the detailed questionnaire sent out as well as for the in-depth interviews. This can be found in Appendix C. The roadmap is accordingly adjusted with the input gained in the iteration activities and priority between recommendations and actions are fixed.

The stakeholders included were chosen from an international pool of experts from different levels of the power system and the EU with varying perspectives, representing different interests. Representatives included actors from TSOs, DSOs, policy groups, interest groups, business organisations, and other market participants.

The deliverable including the final version of the roadmap is thereafter reviewed by the CoordiNet partners and management team.

3. Regulatory context and market definition for the CoordiNet flexibility services

To get a better understanding of the context upon which the analysis is performed the current regulatory framework driving the implementation of flexibility markets is presented in this chapter together with descriptions of some key concepts in flexibility market design, products, and services.

3.1. Regulatory drivers for flexibility market implementation

In order to harmonise and liberalise the EU's Internal Energy Market (IEM) regulations, measures have been adopted to address market access, transparency and regulation, consumer protection, supporting interconnection, and adequate levels of supply. In 2019 the EU put forth a significant update to these regulations to build a more competitive, customer-centred, flexible, and non-discriminatory EU electricity market with market-based supply prices defined as the default approach for market set up. This regulatory package is called the Clean energy for all Europeans package, or simply the Clean Energy Package (CEP), and consists of one directive (Electricity Directive 2019/944/EU) and three regulations: the Electricity Regulation (2019/943/EU), the Risk-Preparedness Regulation (2019/941/EU), and the EU Agency for the Cooperation of Energy Regulators (ACER) Regulation (2019/942/EU) (10). The CEP was first proposed by the EC late in 2016[3], and is now in the last stage of political approval. When launching the consultation for what would become the CEP, the EC stated that "closer cooperation between DSOs and TSOs on issues around network planning and operations is […] paramount and should be pursued" (11). The CEP makes up one of the two most relevant and comprehensive sets of regulations to consider in relation to flexibility markets, the other being the Network Codes (NC).

The first NCs were published between 2015 and 2017 and are currently being implemented. The EC also asked ACER to develop and submit a non-binding framework guideline, setting out clear and objective principles for the development of a network code on demand response, currently out for public consultation (12).

Both sets of regulation bring important definitions to increase TSO-DSO cooperation, as well as market rules and technical capacities for new generators and demand. When definitions are not provided, general directions are given. In this sense, these regulatory documents are important for Research and Development (R&D) projects like CoordiNet as it provides the view of the EC and European Parliament (EP).

3.1.1. The CEP

As the central pieces of legislation in the CEP, the Electricity Regulation (13) and the Electricity Directive (14) both clearly express the need for enhanced coordination between grid operators. The EU electricity market directive and regulation requires:

- Coordination between network operators at different voltage levels to increase efficiency in the use of flexible resources.
- Redispatching of generation and redispatching of demand response shall be based on objective, transparent, and non-discriminatory criteria. It shall be open to all generation

[3] As the Clean Energy package was first proposed in November of 2016, it is also known as the "Winter Package".

technologies, all energy storage, and all demand response, including those located in other Member States unless technically not feasible. The redispatch shall be market based unless this option is proven unfeasible (13).

3.1.2. Electricity Regulation

Article 53 of the Electricity Regulation addresses TSO-DSO coordination and highlights two main things; Firstly, the need for data exchange, and secondly, the need to allow DER to provide services for both the TSO and DSO (Figure 4). Regarding data exchange, the legislation also details that this data exchange should serve both planning and operation purposes and should be done in the different time-steps of power systems operation. In short, the Regulation clearly states the need for TSO-DSO cooperation, and it emphasises that DSOs should be financially incentivised to use DER.

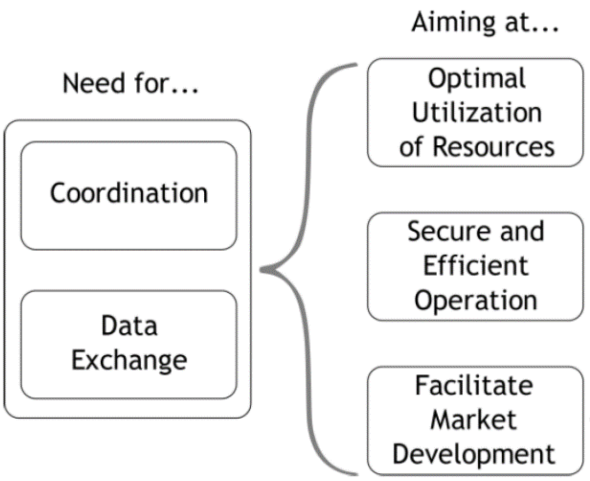


Figure 4. TSO-DSO Coordination in the Clean Energy Package as presented in CoordiNet deliverable D1.1 (15).

Besides Article 53, other topics concerning TSO-DSO interaction are also present in the Regulation. In particular, the new roles for DSOs are especially emphasised throughout the CEP. In the Explanatory Memorandum of the Regulation, the EC states that: “Allowing [DSOs] to manage some of the challenges associated with variable generation more locally (e.g., by managing local flexibility resources) could significantly reduce network costs”. The Regulation also recognizes that for the active management to happen, the proper incentives must be in place. Article 16 (8) states that “regulatory authorities shall provide incentives to [DSOs] to procure services for the operation and development of their networks and integrate innovative solutions in the distribution systems”.

On the one hand, the Regulation states the need for DSOs to procure services and use flexible resources. On the other hand, the Regulation also establishes principles for flexibility providers to be able to provide these services in a transparent and non-discriminatory way. That is, the case when the Regulation states that charges for access to networks “shall not discriminate against energy storage and shall not create disincentives for participation in demand response”. Moreover, “they shall be applied in a way which does not discriminate between production connected at the distribution level and production connected at the transmission level, either positively or negatively”.

Finally, the Regulation also defines the creation of the "EU DSO entity", equivalent to what ENTSO-E is for TSOs. The first task defined for the EU DSO entity in Article 51 is to ensure "coordinated operation and planning of transmission and distribution networks" (1).

3.1.3. Electricity Directive

The Electricity Directive reinforces the need for DER integration in energy and service markets. For the DSO, it highlights the need to allow and incentivise DSOs to procure local services from DERs in article 31, indicating that the the DSO "shall procure the non-frequency ancillary services needed for its system in accordance with transparent, non-discriminatory and market-based procedures,…". Regarding the TSO, Article 40 states the the tasks of the transmission system operator should include that the TSO "shall procure balancing services subject to … market-based procedures" and " participation of all … market participants, including … market participants engaged in demand response … and …in aggregation", thereby also mandates the TSO to open-up for flexibility procurement from DERs (14).

The Electricity Directive is equally important for enhancing TSO-DSO interaction. The only direct mention to TSO-DSO coordination is made in Article 32, paragraph 2, stating that "[DSOs] shall exchange all necessary information and coordinate with [TSOs] in order to ensure the optimal utilisation of resources, ensure the secure and efficient operation of the system and facilitate market development" (14). Although this mention is short, it is very illustrative of the EC's view of the need for enhanced coordination. It highlights three main objectives. Firstly, the optimal utilisation of resources, meaning better exploitation of the potential offered by flexible resources. Secondly, the secure and efficient operation of the system. For example, situations where the activation of DER by the TSO for balancing purposes create local congestion for the DSO, and the elimination of local congestion by the DSO limit the TSO to activate certain DER for balancing purposes must be mitigated. Thirdly, the Directive points to the need to facilitate market development. This can be interpreted as fostering the integration of DER into energy and services markets.

Moreover, Article 32 gives more details on how DSOs should use the flexibility from DER. It states that the Member States should provide the necessary regulatory framework to allow and incentivise DSOs to use such services when such services cost-effectively supplant the need to upgrade or replace electricity capacity and thereby supporting the efficient and secure operation of the distribution system. Article 32 (1a) further defines that:

> "Distribution system operators shall be adequately remunerated for the procurement of such services in order to recover at least the corresponding reasonable costs, including the necessary information and communication technologies expenses and infrastructure costs."

3.1.4. Network codes

The NC and Guidelines (GL) are a set of European regulations co-developed by ENTSO-E and ACER to harmonise procedures across Europe and contribute to the integration and efficiency of the European electricity market (16). Both share the same legal value and are directly applicable to the Member States. The main differences are in the development and implementation processes (17). The GLs include processes in which a set of TSOs at Pan-European or Regional level must develop a methodology, carry out a public consultation, and submit it to national regulators for approval. The NCs, however, do not include these processes and are ready for implementation. In this sense, one may argue that the NCs are more detailed while the GLs are more flexible and leave some aspects to be defined later.

The codes are divided into three families, namely the connection codes, the operation codes, and the market codes. Table 2 lists the eight codes, their families, acronyms, and their type.

Table 2. The network codes and guidelines. Sourced from CoordiNet deliverable D1.1 (15).

Family	Code	Acronym	Type	Regulation reference
Connection	Demand Connection Code	DCC	NC	(EU) 2016/1388
	Requirements for Generators	RfG	NC	(EU) 2016/631
	High Voltage Direct Current Connections	HVDC	NC	(EU) 2016/1447
Operation	Emergency and Restoration Code	ER	NC	(EU) 2017/2196
	Transmission System Operation	SOGL	GL	(EU) 2017/1485
Market	Capacity Allocation and Congestion Management	CACM	GL	(EU) 1222/2015
	Electricity Balancing	EBGL	GL	(EU) 2017/2195
	Forward Capacity Allocation	FCA	NC	(EU) 2016/1719

The NCs are mostly devoted to pan-European grids and markets and therefore more related to the transmission networks. Nevertheless, some NCs are relevant for the TSO-DSO coordination discussion. Title III of the Demand Connection Code (DCC), for instance, sets the connection rules for demand units that may provide demand response services to system operators (SO).

The System Operation Guideline (SOGL) is also relevant for TSO-DSO coordination. According to Article 1, one of the objectives of the SOGL is to establish "rules and responsibilities for the coordination and data exchange between TSOs, between TSOs and DSOs, and between TSOs or DSOs and Significant Grid Users (SGUs), in operational planning and in close to real-time operation". The SOGL also establishes that TSOs and DSOs should cooperate in the case of reserve providing units or groups[4] connected to the DSO grid. Article 182 sets guidelines on the TSO-DSO coordination for balancing, as well as the prequalification process, establishing that:

- The necessary information exchange regarding the providing units should be agreed between TSO and DSOs.
- The prequalification process shall rely on the agreed timeline and rules concerning information exchanges and the delivery of active power reserves between the TSO, the reserve connecting DSO and the intermediate DSOs. The prequalification process shall have a maximum duration of 3 months from the submission of a complete formal application by the reserve providing unit or group.
- DSOs, in cooperation with the TSO, shall have the right to set limits to or exclude the delivery of active power reserves located in its distribution system, based on technical reasons such as the geographical location of the reserve providing units and reserve providing groups.
- Each DSO shall have the right, in cooperation with the TSO, to set, before the activation of reserves, temporary limits to the delivery of active power reserves located in its distribution system. The respective TSOs shall agree with their reserve connecting DSOs and intermediate DSOs on the applicable procedures.

[4] According to the SOGL, a 'reserve provider' means a legal entity with a legal or contractual obligation to supply Frequency Containment Reserve (FCR), FRR or RR from at least one reserve providing unit or reserve providing group

The Electricity Balancing Guideline (EBGL) is also important for the TSO-DSO discussion as it paves the way for the definitions of balancing products and services and sets the rules for TSOs to develop pan-European platforms for balancing provision. The organisation of balancing markets, however, still varies significantly across the EU countries, but agreements are being made as requested by the EBGL. The EBGL "lays down a detailed guideline on electricity balancing including the establishment of common principles for the procurement and the settlement of frequency containment reserves, frequency restoration reserves, and replacement reserves and a common methodology for the activation of frequency restoration reserves and replacement reserves" (18). The regulation shall be applied to all TSOs and to the national regulatory authorities (NRA) in the EU. The regulation does specify the cooperation with DSOs and indirectly address the provision of balancing services by DER by stating that the rules governing balancing shall "ensure adequate competition based on a level-playing field between market participants, including demand-response aggregators and assets located at the distribution level" (18).

3.2. Overview of key concepts in flexibility markets

Before presenting the CoordiNet roadmap it is important to get an overview of key concepts and how they were applied in the demonstrations. This is provided to get a better understanding of the results and the contexts in which they were achieved.

3.2.1. Coordination schemes

Schemes for the coordination of service procurement by DSOs and TSOs provide a structure of how flexibility can be procured by different SOs in a coordinated and grid safe manner. Such market coordination schemes must be put in place, considering several aspects of the utilisation of flexibility from DERs (15). In addition, a coordination scheme is defined in Gerard et. al. as "the relation between TSO and DSO, defining the roles and responsibilities of each system operator, when procuring and using system services provided by the distribution grid" (19). Following this definition, it is also possible to highlighting two important ingredients for coordination: (i) the assignment of responsibilities to and the interaction between system operators, (ii) the focus on the specific market phases of procurement and activation of flexibility sources and how this market phase should be organised through proper market design. However, as recognised by Smartnet, in certain occasions, other market phases (such as pre-qualification, activation and settlement) could also require specific coordination (20). An initial mapping of coordination schemes and a common nomenclature for the project was proposed by introducing classification layers that highlight the differences between the coordination schemes tested in the CoordiNet demonstrations (21). For an overview of this common nomenclature see Figure 5 below.

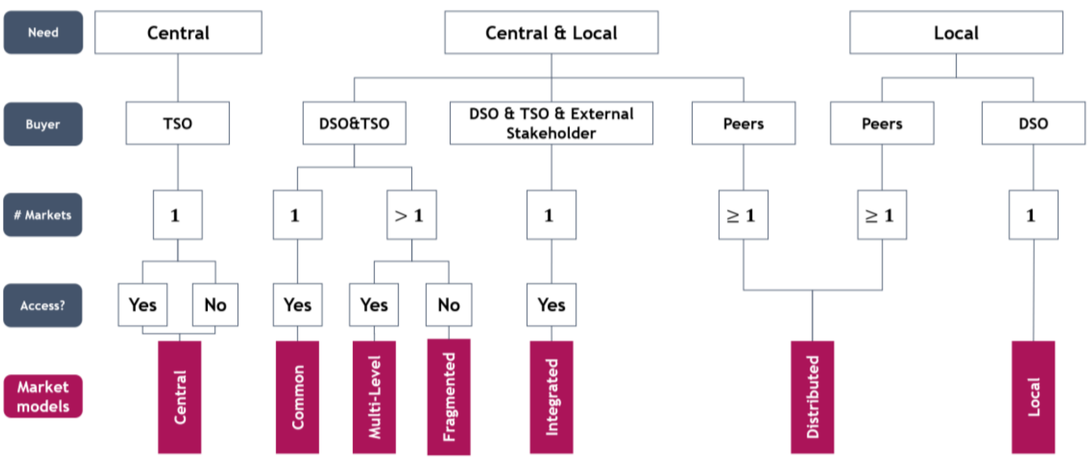


Figure 5. Different TSO-DSO coordination schemes defined in CoordiNet deliverable D1.3 **(2)**.

Among these different approaches to market coordination the local, central, common, multi-level, fragmented, and distributed coordination schemes were tested in CoordiNet (Figure 6). A more detailed definition and characteristics of these coordination schemes can be found in CoordiNet deliverable D1.3 (22).

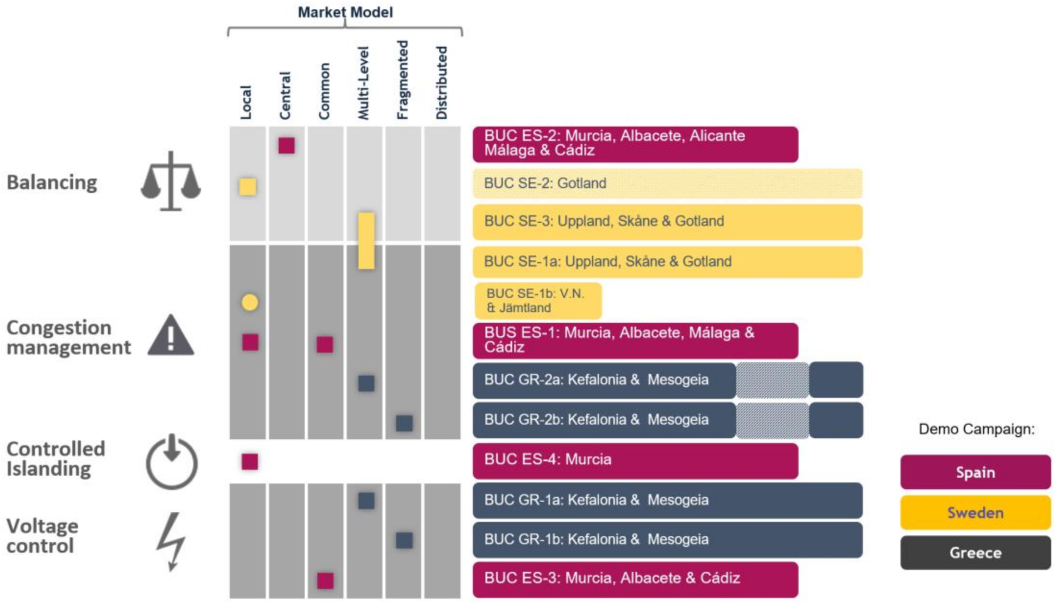


Figure 6. An overview of the coordination schemes tested in the CoordiNet demonstrations.

3.2.2. Flexibility services and products

In the CoordiNet project the distinction of services is made between services for the TSO, and services for the DSO. These services are also referred to as "system services" and can be seen in Figure 7.

- Services for TSO: frequency control (balancing), congestion management, voltage control, inertia, and black start.
- Services for DSOs: local congestion management, voltage control, islanded operation, and black start.

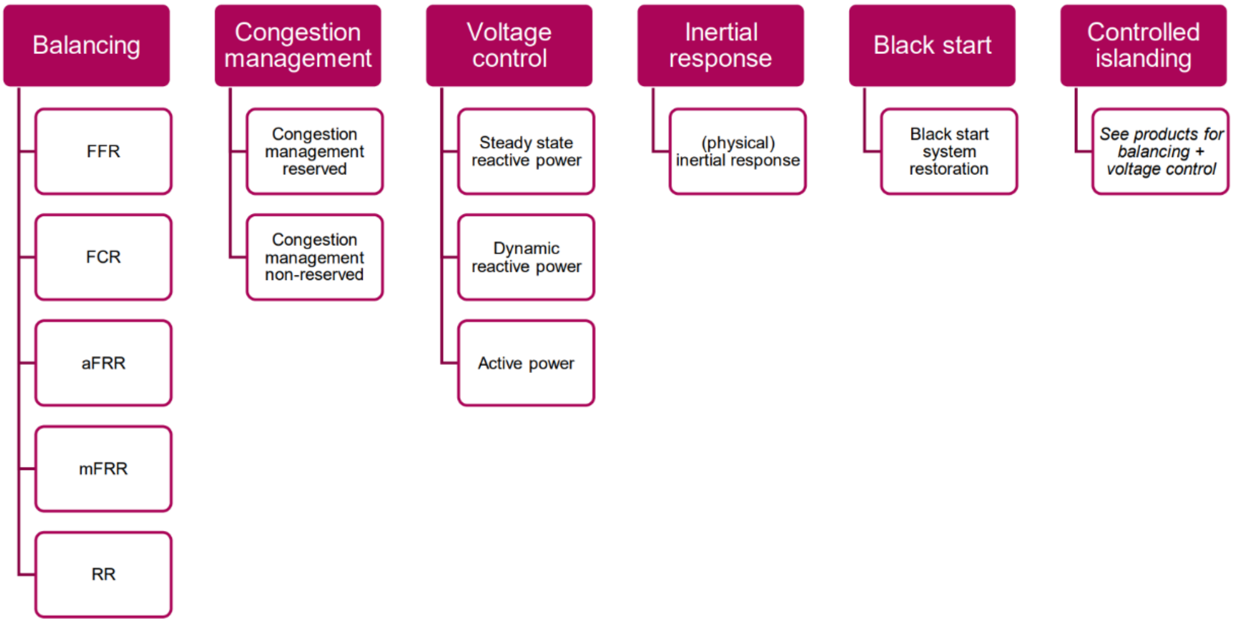


Figure 7. Products for system services defined in CoordiNet deliverable D1.3 **(22)**.

TSO and DSO procurement of these services from DER is still incipient, particularly for DERs connected at low voltage levels. Considering the three demo countries, in none of them, DSOs could directly procure services for grid management (15). On the TSO side, however, DER already take part in service provision, but somewhat limited. In general, balancing is the main product offered by DER. However, although DER is already participating in these markets, the participation is limited to certain types and sizes of DER (15).

3.2.2.1. Energy-only and capacity products

Before proceeding, the distinction between energy-only and capacity products should be made. Within the EBGL (18), energy-only products pertain to services that do not involve a separate reservation and activation stage; capacity products involve reserved (idle) capacities that the respective provider has committed in holding and the procuring entity can activate at a specified future horizon (not immediately). In other words, capacity products correspond to the availability commitment in capacity (usually, but not necessarily so, accompanied by an availability remuneration) of the different system services procured by TSOs or DSOs, while energy products correspond to the activation stage (usually accompanied by an activation price) of such services. The added value of capacity products is closely linked to the European decarbonisation agenda, which entails renewable energy generation that is inherently characterised by high variability and limited predictability, controllability, and inertia. The distinction between capacity and energy products, can also be linked to the procurement cycle and be extracted from the definition of the pricing scheme (i.e., availability price for a capacity product and/or activation price for the energy product) and the validity period of the bid (2).

3.2.2.2. Procurement horizons

A differentiation of the required flexibility types and their time scales is also needed when discussing flexibility services and products. Long-term flexibility services are contracted weeks, months and even years ahead to anticipate long-term developments. As reported by (23) long-term needs could, for example, relate to hydro-electric reservoir storage or commissioning of new power plants. In contrast, medium-term flexibility (1 hour – few days in advance) is required in the intra-day (ID) and day-ahead (DA) market time scales to match the grid generation and supply while adapting to updated predictions from variable RES. While, when moving to real-time balancing operation, short-term flexibility (≈ few seconds - 15 minutes) is required (23).

Since the TSO-DSO coordination is most challenging in the medium- and short-term timeframes, the CoordiNet project and the analysis made is focusing on the period ranging from a few days in advance, in this report referring to this as short-term flexibility. For the TSO balancing markets, services with a procurement horizon up to a few seconds in advance before delivery of the flexibility are also relevant and referred to when specifically mentioned in this deliverable.

3.2.3. Business Use Cases

Figure 8 illustrates the full scope of the CoordiNet demonstration activities and the standardised products, system services, and coordination schemes, which were included in the project scope. As can be seen in the illustration below, each demonstration activity tested different products, applied different market time frames, and included different types of flexibility service providers (FSP) that provided flexibility through various DER technologies. These different combinations of products, services, and coordination schemes were coupled with a distinct BUC. A detailed description of the different BUCs can be found within deliverable D1.5, *Business use case: Business use case definition* (24).

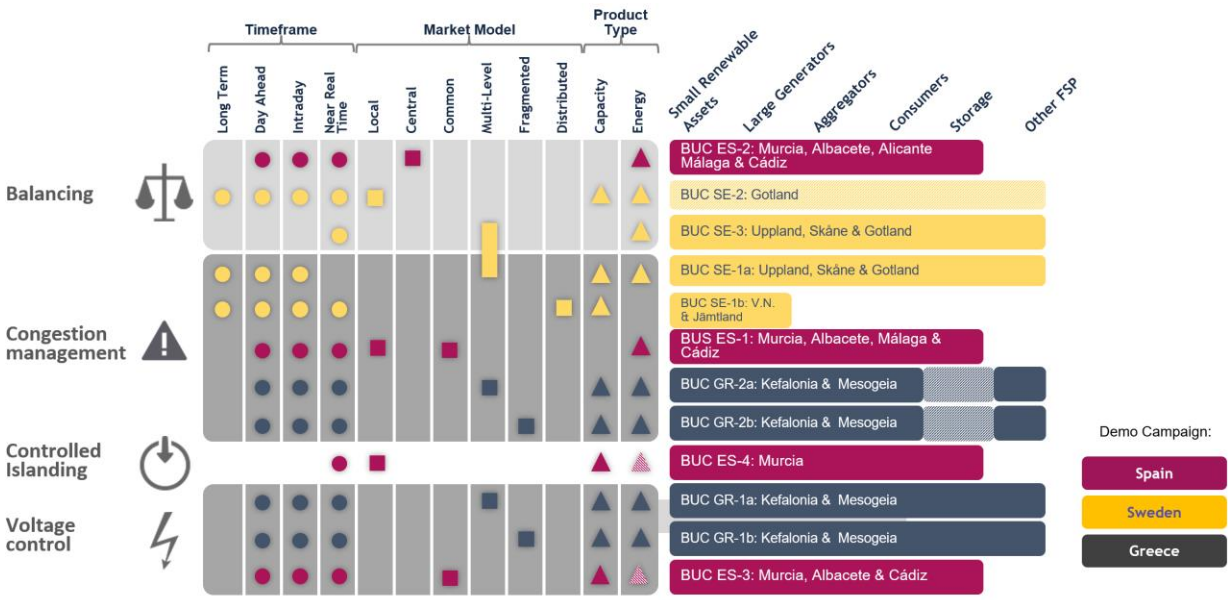


Figure 8. Included activities and the scope of the CoordiNet project. The illustration shows the four products that were tested and in which Business Use Case in Spain (pink), Sweden (yellow), or Greece (grey) they were tested. Characteristics and specifications

With the defined BUCs, deliverable D1.5 of the CoordiNet project described generic functional specifications of the system services that were tested in the demonstration sites, following the approach described in the International Electrotechnical Commission (IEC) 62559 standard (25,26).

3.2.4. Flexibility service providers

DER is a concept used to encompass multiple types of end-users connected to the grid, capable of providing energy and/or services by mobilising the flexibility they have available. However, a distinction can be made between four types of DER. Firstly, generators connected to the distribution grid or to the consumer who must be supplied, which are termed distributed generation (27). Secondly, the active demand, that is also considered a DER, named demand response. Thirdly, energy storage systems. In this category, batteries are also included. Finally, electric vehicles (EV), that act as a type of energy storage with some specific features. Due to their potential importance and connection availability, EVs are considered separately from energy storage (15). Figure 9 summarises these general definitions.

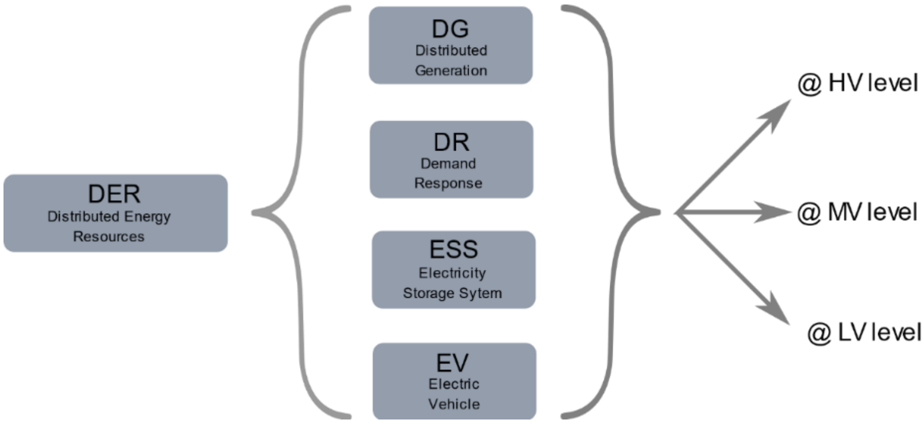


Figure 9. Classification of DER according to their nature and voltage level. Figure sourced from CoordiNet deliverable D1.1 (15).

FSPs are the agents providing flexibility services via different types of DER technologies. FSPs can be a direct owner of flexible resources, which participate in the provision of system services, an intermediary such as an aggregator, or a retailer that represents flexible resources and coordinate their response. It is also important to consider at which voltage level in the grid the resources are connected. For example, distributed generation connected at the distribution high-voltage (HV) level could be a wind farm of 10MW of installed capacity, while distributed generation connected at the low-voltage (LV) level can be a rooftop solar panel system with an installed capacity of 10kW or less. Therefore, these are clearly very different. The same can be said for demand response being provided by a residential consumer or a large industrial consumer.

4. The CoordiNet Roadmap

The implementation of market-based flexibility approaches requires addressing several key considerations, such as technology neutrality, market transparency, and financial viability, which will have to be paid attention to for successful implementation of markets for system services. In CoordiNet deliverable D2.1 the following criteria were determined for market analysis and BUC evaluation:

- Market efficiency (with dimensions including service provision, participation/liquidity, opportunity for gaming, market power),
- Coordination (with dimensions including complexity of coordination mechanism, feasibility of the solution, efficient allocation of resources, transparency of the coordination and solution generation, efficient exchange of relevant data),
- Synergy with current and future EU markets (with dimensions including synergy with current markets and synergy with future designs and regulations),
- Complexity of clearing mechanisms (with dimensions including consideration of network models and type of mathematical formulation) (28).

Market-based approaches for provision of flexibility services will imply advantages and disadvantages that are actor and context contingent. Depending on the system and country of implementation different requirements will have to be considered. Data availability, which influences the type of market-based approach chosen (29), transaction costs, entry or exit barriers, market power, uncertainty in market development, or high implementation costs are all examples of the broad span of considerations that will have to be made (30). In the analysis that follows the CoordiNet experiences will be used, where possible, to give examples of how these factors could be addressed and mitigated. Supporting material is drawn from to provide a comprehensive overview of where key barriers lie for broad implementation of flexibility solutions and what solutions could be provided. The result of the analysis presented in this report is the CoordiNet Roadmap, consisting of five themes describing the main building blocks of new flexibility markets (see Figure 10).

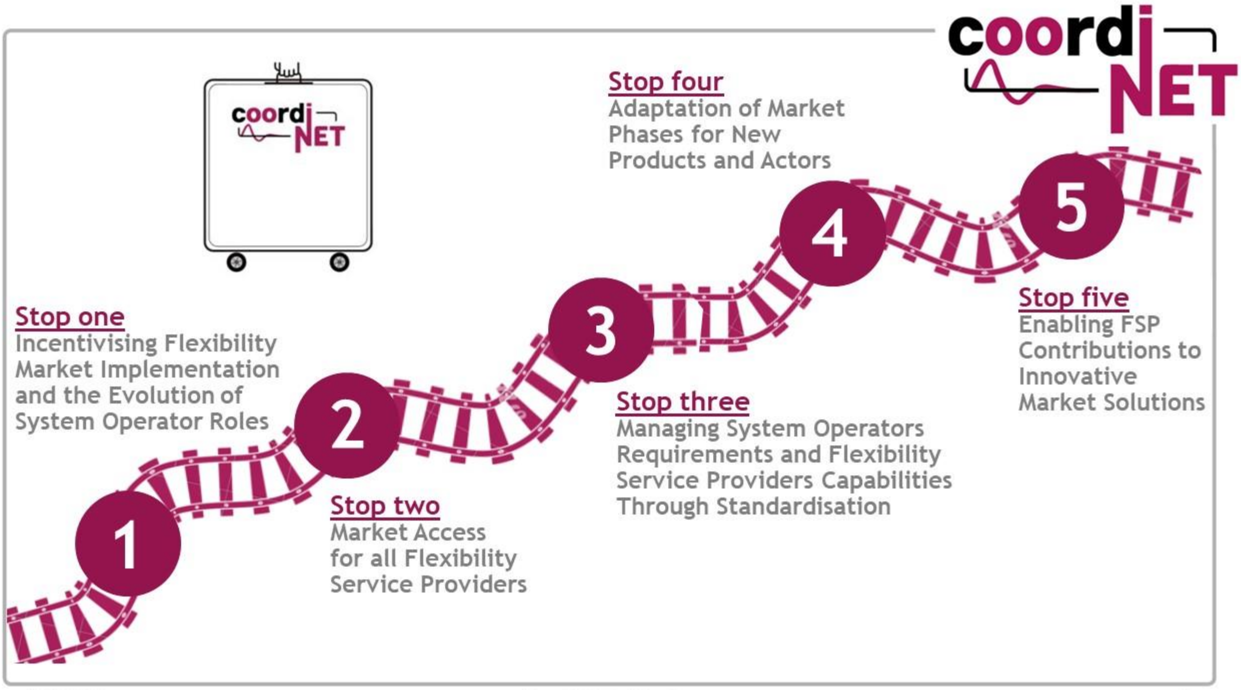


Figure 10. Illustration of the CoordiNet Roadmap with the five stops that summarises the main themes for flexibility market implementation.

These themes emerged throughout the project within the demonstration sites and the experiences gained in the three participating Member States. These themes were supported by the topics, or building blocks, defined in the initial stages of developing the Roadmap. These building blocks are presented in Table 3.

Table 3. Table showing the topics that are incorporated within each stop along the CoordiNet Roadmap.

The five themes of the Coordinet Roadmap	Building blocks for new flexibility markets	
Theme one: Incentivising the evolution of SO roles and creation of flexibility markets	Roles and responsibilities	
	Requirements for information sharing	
	Choice of coordination scheme	
	Grid decision support tools	
Theme two: Market access for all flexibility service providers	Aggregation	
	Customer engagement	
	Baseline methodology	
Theme three: Managing system operator requirements and flexibility service providers capabilities through standardisation	Level of product standardisation	
	Procurement of capacity vs energy	
Theme four: Adaptation of Market Phases for New Products and Actors	Timing aspects and integration of new flexibility markets	
	Prequalification requirements	
	Procurement and activation	Market clearing, bid selection, and pricing
		Geographical scope and network representation
	Settlement	Requirements of settlement process
		Baseline methodology
		Requirements for information sharing
Theme five: Enabling flexibility service providers contributions to innovative market solutions	Markets and products for reactive power	
	Peer-2-Peer markets for system services	

4.1. Theme 1: Incentivising the evolution of SO roles and creation of flexibility markets

The Challenge: The electrification of loads and consumers along with increasing shares of RES connected to the distribution grids drives the need for SOs to implement flexibility solutions to utilise existing grids more efficiently. To ensure secure electricity delivery, the coordination between TSOs and DSOs will have to increase as the flows within the different levels of the system shift, moving from being strictly one directional with centralised production towards including increasing shares of DER and flexible energy consumers and storage units. To manage these new flows there is a need for SOs to develop new market solutions that would enable procurement of system services, as defined in the CEP. However, the responsibilities and incentives for SOs to realise these solutions is not as clear.

Key Take-Aways from The Coordinet Experience:

Investment needs and incentives
The CoordiNet demonstrations highlight that current national economic regulation does not allow SOs to recuperate their investments and costs for new market solutions for system services. To enable this, the cost of establishing these markets and mobilising flexibility must be recognised in SOs remuneration schemes.

The benefits of flexibility solutions have society-wide effects and public institutions could play a more active role in promoting both flexibility and efficiency solutions.

Roles and responsibilities
CoordiNet recommend to define clear roles and responsibilities in new established flexibility markets including both actual and new agents involved in these processes. To support this a common EU-level definition of roles and responsibilities should be included in the new network codes for demand side flexibility on distribution level.

Especially for DSOs, flexibility markets will come with new roles and responsibilities. Flexibility procurement will require a different approach to planning their operations. To enable DSOs to work proactively and complement current near real-time operational practices, with longer procurement horizons, NRAs should take into consideration procurement of flexibility, to mitigate structural congestion, in the Network Development Plan.

Increased SO coordination
The implications of new resources connected to both TSO and DSO networks have to be properly accounted for as well as the impact of demand growth which may affect the reinforcement requirements of networks. However, if grid planning is done in a coordinated manner, reinforcement needs may actually be reduced for both grid operators with the implementation of flexibility markets. Higher coordination will help limit any negative effect and consequence of flexibility procurement on other voltage levels and in the long-term enable flexibility markets to scale up. In addition, higher coordination will result in maximising the overall procurement efficiency.

Market design and coordination schemes
To establish liquidity and attract FSPs in the early stage of development of flexibility markets, simple market coordination schemes are recommended. With time, a more complex approach, where both DSO and TSO have access to the same market, should be explored, as it could result in more efficient market optimisation. Coordination schemes that allows for a common pool of flexibility resources for SOs would result in higher complexity but would enable the maximisation of social welfare, i.e. the maximising of surplus for both buyers and sellers, as the offered flexibility can concurrently serve the needs of multiple SOs and increase overall market liquidity.

Across Europe the energy sector is in the middle of a re-structuring and modernisation process aimed to reach a unified energy market. During this re-structuring the interaction between TSO and DSO is expected to evolve for several reasons. With a higher share of DER connected to the distribution grid the role of the DSO should change and become more active to deal with new challenges. In addition, electrification of loads and consumers, transport, heating, etc, may increase the aggregated electricity demand and necessitate the improvement of the interaction between DSO and TSO. These increased interactions with DERs to provide system services creates a situation where interactions between SOs will need to be more coordinated. In the ENTSO-E position paper *Towards smarter grids: Developing TSO and DSO roles and interactions for the benefit of consumers* (31), it is explained how technical requirements for an evolved interaction between TSOs and DSOs can be met with currently available technological solutions. However, several non-technical issues can be identified which are closely related to the regulated environment SOs are operating in. In this theme, the most important aspects resulting from the CoordiNet experience, for incentivising the evolution of SO roles and the creation of flexibility markets will be discussed. In the following, we will discuss economic incentives for implementation, planning, forecasts and operational tools, roles and responsibilities, as well as SO coordination through choice of coordination schemes.

Infobox A. Key challenges for system operators in the new energy system regime.

Some key challenges for system operators in the new energy system regime

The main challenge for DSOs under a large-scale electrification of the transport and heat sectors lies in managing the emerging large demand peaks in a cost-efficient fashion. In contrast to TSOs, DSOs have traditionally operated and developed their networks in a passive fashion, relying mostly on conventional network reinforcements and the limited controllability of network assets (e.g., on-load tap changers, reactive compensators). However, DERs have the capability to control their active and reactive power in order to limit power flows and consequently avoid or defer capital-intensive reinforcements. As a result, more and more European DSOs have started considering more active approaches for the operation of their networks, including market-based procurement of system services from their network users (5).

The main challenge of TSOs under a large-scale deployment of renewables lies in managing the demand-supply balance of the system on a real-time basis and maintaining frequency within the statutory limits, in order to safeguard the operation of the whole system. In this context, European TSOs procure different balancing services from electricity market participants (6). DERs have the capability to contribute to the provision of such balancing services, thereby increasing the level of competition in the balancing markets and reducing the balancing costs of the system. They can do so by offering the capacity of increasing or reducing their produced or consumed power with respect to the levels prescribed by their energy trading activities, in case an imbalance occurs between the total generation and total demand in the system.

4.1.1. Regulatory context

As presented in Chapter 3, the CEP mandates DSOs to take advantage of flexibility resources by integrating them in both planning and operation tools using market mechanisms to select the most efficient resources (32). The activities in the CoordiNet project and this analysis have resulted in insights regarding novel aspects of market-based solutions. These insights naturally concern the barriers that DSOs might face in implementing flexibility markets for congestion management and voltage control, as the expectations for their market activities change over time. Regulation regarding TSO balancing markets is already existing, including a list of methodologies defined in the scope of the EBGL and these markets are to a higher extent established and implemented across the EU's Member States (18). Although, to enable DERs to also contribute to balancing markets, already established rules and guidelines should be revised regarding technology neutrality to eliminate barriers for TSOs to procure system services from DER. *Likewise, the potential impacts of flexibility markets on already established markets (balancing or re-dispatching) should* *be evaluated as these might require the amendment of some Network Codes, such as the CACM, SOGL, or the EBGL (Action – Recommendation 1.1).*

Even though the CEP mandates the use of flexibility by DSOs, there is no clear definition on how to implement the market-based procurement by DSOs and the interpretation of the CEP articles might be different in different countries/projects. Article 32 of the Electricity Directive also states that DSOs should have incentives to " improve efficiencies in the operation and development of the distribution system" (14). The Electricity Directive also highlight the need for "optimal utilisation of resources, to ensure the secure and efficient operation of the system and to facilitate market development". In this context, current EU regulation promotes the procurement of local flexibility and emphasises that TSOs and DSOs should be coordinated in this process but does not provide a clear definition on the market structure, leaving this to Member States. *New network codes for demand side flexibility on distribution level are already under discussion. These should comprise common EU-level principles on how to design and operate flexibility markets including clarification of the relation between flexibility markets and non-firm connection contracts, considerations for new actors, the definition of how flexibility needs are to be quantified and providing guidelines on which product to use when, etc. However, most of the details should be discussed and decided at national level (Action-Recommendation 1.1)*.

4.1.2. Economic incentives for DSOs to implement flexibility markets

Today new flexibility markets are implemented and sustained through R&D initiatives such as CoordiNet. These R&D initiatives have external financing and are not dependent on the viability and longevity of a real-world business case. The set-up and operation of these new markets come with costs, for example for developing new hardware and software for the market platforms, training of staff, implementation of communication and management systems etc. DSOs should be able to recuperate both investment costs (CAPEX) together with the operations and maintenance costs (OPEX) of the market. The DSOs participating in the CoordiNet project would most likely struggle to carry these costs (33), especially since investments related to market implementation cannot be recovered via the grid tariff. *Before future European regulation allows for such additional funding this will continue to be the case. As such currently, the business case of flexibility markets is insufficient for SOs, especially local actors, to carry the full responsibility of implementation. By providing funds for R&D pilots the financial burdens of implementation of flexibility solutions could be lowered (Action – Recommendation 1.2).* In this new energy system regime, costly CAPEX for grid reinforcements are expected to be reduced, either by deferment or avoidance of investments, as local flexibility would be used to keep grids within limits instead (34). On the other hand, when looking closer at OPEX, it would most likely increase, mainly due to the flexibility procurement cost (34). The CoordiNet deliverable D6.3, *Economic assessment of proposed coordination schemes and products for system services*, has performed an economic assessment of flexibility procurement in comparison to grid reinforcement, and found that until there is enough liquidity in short-term markets, long-term markets are a better option (35). The results in CoordiNet deliverable D6.3 also show that for occasional congestion, flexibility may be more economically efficient than reinforcing the grid. Even when this is not the case, flexibility provides a fast solution that can be implemented in wait of grid reinforcements and that short-term markets, like the ones tested in the CoordiNet demonstrations can be an efficient solution. The analysis also finds that in any case, flexibility will always be the least costly solution than remedial actions or blackouts for unexpected events in the system. For structural congestion, the analysis shows that flexibility can be used to postpone grid reinforcements, but that in this case long-term markets should be used to procure flexibility (35). It is stated in the CEP that system services should be procured "where such services cost-effectively alleviate the need to upgrade or replace electricity capacity and support the efficient and secure operation of the distribution system" (14). Here, economic viability should be ensured by considering flexibility procurement in the Network Development Plans to guide DSOs when planning their networks (29).

The procurement cost of flexibility also varies depending on the chosen pricing model. In the specific case of congestion management, remuneration by product availability might considerably increase operating costs since the remuneration of the products is not only considering the product delivery (variable remuneration), but also the product availability (fixed remuneration). In addition to this, the procurement of many availability products involves availability prices that are fixed over a long temporal interval (often months-ahead or weeks-ahead (long-term markets), although DA (short-term market) procurement is supported by the target model). However, the economic value of capacity products depends massively on system conditions (e.g., demand level, renewable output, system inertia) that change in much faster timescales than the availability prices. This inefficiency can result in a risk of over- or under-procurement of capacity products, with significant cost implications. These products should therefore be procured over shorter timeframes and thus more efficiently reflect the temporal variation in their value for the system. The procurement of availability products by the DSOs are very much relevant for them to assure enough flexibility is available when needed to be able to trust in flexibility markets over reinforcement of grids to assure a secure supply to its customers.

The CoordiNet demonstrations highlight that, current national economic regulations don't allow DSOs to recuperate their investments and costs of new market solutions for system services (**¡Error! No se encuentra el origen de la referencia.**) and thereby do not provide the necessary conditions for DSOs to use flexibility as an alternative to the CAPEX solutions. For that to happen, DSOs need to have the cost of procuring and mobilizing flexibility recognized in their remuneration schemes, and, potentially, some economic incentives to opt for the flexibility solution when this is more efficient. If not, this could lead to a situation in which DSOs would opt for grid reinforcement while from an energy and resource efficiency perspective, this would be the sub-optimal course of action. However, in cases where grid reinforcement will be necessary DSOs must consider the time needed to put such reinforcement in place. The use of flexibility to alleviate, for example grid congestion, during this period should be considered.

Table 4. Summary of the economic regulatory frameworks for DSOs in the three CoordiNet demonstration countries.

Demo country	Current economic regulation
Greece	The regulatory framework in Greece recently transitioned from a cost-of-service scheme to an incentive regulation with a 4-year regulatory period. The first regulatory period goes from 2021 to 2024 (36). Within the new regulation, CAPEX and OPEX are regulated separately. According to the recent law (NRA's decision) on the methodology of DSO's revenue calculation, there are also separate incentive mechanisms in order to increase the efficiency of controlled OPEX and perform projects of major importance. A premium Weighted Average Cost of Capital (WACC) is provided for these projects of major importance, including those that contribute to the facilitation of increase in DER penetration and smart grid implementation. There are no incentives for continuity of supply in the first regulatory period. It is not defined yet if they will be implemented in the second regulatory period.
Spain	DSOs in Spain are under a revenue cap regulation with six-year periods, being the current one 2020-2025. CAPEX and OPEX remuneration are calculated separately considering the information reported by DSOs and a set of tables of standard costs for different asset categories. Deviations between standard and actual costs are capped and these must be justified if they exceed a certain threshold. The remuneration is therefore largely proportional to the volume of investments made by the DSO. New distribution investments are included into the Regulated Asset Base (RAB) and start to be remunerated with a delay of two years, i.e., assets put into service in year n-2 start being included in the remuneration of year n. The rate of return is determined following the WACC approach. Spanish DSOs are subject to a bonus-malus incentive on continuity of supply. Moreover, there is a cap mechanism for OPEX, known as "manageable component" (COMGES for the abbreviation in Spanish "COMponente GEStionable") which aims to incentivise efficiencies in the management of OPEX by DSO and the TSO has an economic incentive to minimise the annual re-dispatched energy.

Sweden	The Swedish economic regulation for DSOs is set as an incentive regulation with a revenue cap in a 4-year regulatory period. The CAPEX and OPEX are calculated separately. OPEX is based on the company's own historical cost and with an efficiency target. Efficiency targets are based on national benchmarking, using Data Envelopment Analysis (DEA) simulations. On the CAPEX side, calculation is based on standard cost for all assets, this gives incentives to invest to a lower cost than the standard cost. In Sweden, the DSOs are responsible for buying the losses, and a symmetric bonus-malus for continuity of supply indexes exists (SAIDI, SAIFI and LV ENS, both planned and unplanned). Apart from the revenue cap, it is important to mention that Swedish DSOs (regional and local) are subject to subscription limits at the substations connecting to the next SO. Therefore, an incentive for flexibility procurement does exist.

To give the necessary financial incentive, especially for the DSO, a full regulatory revision is required to assure adequate support to establish flexibility market mechanisms (Recommendation 1.1). The procurement of local flexibility services requires to update the economic regulation for DSOs to consider the cost of implementing and using flexibility markets and implement efficient incentives to use this choice instead of the traditional grid investment when appropriate. However, the overall cost-efficiency must be optimised against a long-term perspective, with the aim of society wide electrification, which could result in short-term cost inefficiency. Other DSO capabilities such as increasing grid connections or grid efficiency could be incentivised via the remuneration scheme in a transitional period (Action-Recommendation 1.1). The way the incentive regulation is set matters. It is traditionally set either over the OPEX alone (letting the CAPEX be a pass-through component), or over the TOTEX (total expenditure). Historically, the former setting was firstly adopted, providing the signal to DSOs to build a strong network (investments were incentivised, as they are remunerated) and providing an incentive to reduce inefficiencies in the management of the companies, which made sense in a framework with important growths in the electricity demand. However, in the perspective of a high penetration of DER and the possibility of such resources providing flexibility to avoid reinforcement, this CAPEX-bias ends up providing little incentive for the procurement of flexibility. An analysis made in the deliverable D6.4 of CoordiNet including the three CoordiNet demo countries and an additional five European Member States, showed that none of these countries has yet implemented a regulatory framework for the cost recognition or output incentives for use of flexibility (37). *Regulatory sandboxes could be an efficient way to provide an evidence base for regulatory bodies to determine what regulatory updates are needed to fit with current and future market formations. (Action – Recommendation 1.2).*

As mentioned above, in addition to the CAPEX/OPEX treatment, economic regulation may also include additional components to the DSO's revenue formula in order to provide target-specific incentives. A widely used example of such an incentive is the incentive to reduce losses by including a bonus (or penalty) to the remuneration, by obliging the DSO to buy their own losses. Additionally, quality of supply can be incentivised, also by providing bonus/penalties based on pre-established indicators (e.g., SAIFI, SAIDI). The latter can be especially important for the controlled islanding service in CoordiNet, which is a service including both congestion management and balancing for isolated regions such as an island. Most countries have continuity of supply incentives, which would already provide an incentive for this service (37).

As the grid tariffs are the income for the DSO and should cover and pay the incentives needed, it is important that these are well-designed and also take the procurement of flexibility into consideration. The proposed Energy Efficiency Directive states that:

> "Network tariffs shall be cost-reflective of cost-savings in networks achieved from demand-side and demand-response measures and distributed generation, including savings from lowering the cost of delivery or of network investment and a more optimal operation of the network." (38)

This might create an issue, as a change in tariff might affect the flexibility needed by the DSO. A decrease of the tariffs due to less expenses in terms of grid reinforcement might indirectly incentivise an increased consumption by connected units. In a grid which already has problems with congestion, this would increase the need of flexibility even more. It is therefore important that both implicit and explicit flexibility needs provide coordinated economic incentives for the DSO. *Therefore, grid tariffs should be revised, if not already designed to, to coordinate the implicit flexibility and the explicit flexibility (Action – Recommendation 1.1).*

Beyond the need for revising remuneration schemes and creating stronger incentives for DSOs to implement flexibility markets, the society-wide effects of flexibility solutions point towards the need for public institutions to play a more active role in promoting both flexibility and efficiency solutions. Clear and reliable information from these actors to FSPs and the broader public, regarding flexibility markets, including relevant information on the products for system services, is needed (Action-Recommendation 1.2).

4.1.3. Planning, forecasts, and operation tools

For the SO to procure flexibility, an important aspect is knowing how much flexibility is needed. Careful planning built on good forecast is therefore crucial to be able to take good decisions regarding when and where to buy flexibility. As will be discussed later in this chapter, the DSO must work more proactively with their grid operation and extend their planning over longer time horizons with the implementation of flexibility markets. When it comes to structural congestion, long-term planning is an important tool to evaluate and possibly secure flexibility over longer time periods. This can make flexibility a valid choice and avoid, at least temporarily, reinforcement of the grid. During the planning phase, the implications of new resources connected at both TSO and DSO networks have to be properly accounted for as well as the impact of demand growth that may affect the reinforcement requirements of networks. Since the TSO has extended experience in working with ancillary services for the transmission grid, EU regulation has been developed for the calculation of resource adequacy that clearly defines requirements for certain tools and algorithms for grid decision support for the transmission system. An EU planning methodology is defined in the Ten-Year Network Development Plan (TYNDP) (39), developed by ENTSO-E and ACER, but for DSOs a similar methodology does not exist on EU level. Flexibility is already considered as an additional input variable in the TYNDP for the transmission grid and should also be included in future regulation for long-term planning of the distribution grid. If done in a coordinated manner and by utilising local flexibility, reinforcement needs may actually be reduced for both grid operators. With current regulation, network planning is usually done on the safe side, an example of this can be seen in the Greek demonstration, where in some regions, there is a stop on new connections of RES and new consumers while new lines are being built. Thereby preventing the share of RES and electrification in the system to increase (40).

Long-term planning has not been considered in detail in the CoordiNet project, where instead the focus has been on operational planning that has a shorter time perspective. Short-term planning and flexibility need quantification is also an important aspect when establishing flexibility markets for the DSO to not only operate the grid in real-time as was traditionally done. An effort has been done within the CoordiNet demonstrations to develop planning and forecast tools for the DSOs to cope with grid decision-making and flexibility procurement. *To secure liquidity in flexibility markets, the DSO should work with longer operational planning horizons and put more effort on forecasting models and tools. The grid planning at the distribution level should be coordinated with the grid planning at the transmission level. Finally, a holistic approach should be considered to consider other energy carriers, such as hydrogen (Action-Recommendation 1.4).*

Still today, on each of the functional levels the developed tools to support grid decision processes have not reached a mature and standardised state. This can hinder the development of increased demand side flexibility. However, the extensive experience from the TSO applying the TYNDP in the transmission system, naturally fosters software development in this area, since developing and deploying required algorithms is compulsory for each system operator (13). The experience from already developed decision support tools for TSOs could also be of use for DSOs for operational planning or for the interface between higher- and lower-level systems. Risk management for critical grid situations very much moves to real-time adjustments in the grid as the change of the energy profiles of different types of DERs does not only affect the DSO but also the overall system, for instance in terms of balancing. Thus, there is a strong connection to technical tools on the system operators' side, such as grid reconfiguration (41).

To correctly evaluate grid status, performing operational planning and monitoring, a common approach to communication between SOs should be developed to enable the emerging information needs for the establishment of flexibility markets (Action-Recommendation 1.5). However, frameworks for these tools do not take into consideration DSO's specific contexts since this application is still fairly new. DSOs in the CoordiNet demonstrations expressed a need for access to a similar set of tools as are available for TSOs and it could be assumed that the majority of European DSOs experience the same need (42). The need for salient forecast tools and established methods for defining and quantifying the flexibility need will be an important part of the puzzle which will be discussed more in detail in the following. However, there is no one-size-fits-all technical solution supporting decision making for all flexibility market stakeholders.

An analysis was conducted on which tools already exist, which functionalities could be achieved by a slight modification of existing tools, and finally which tools have to be developed from scratch (see Figure 11**¡Error! No se encuentra el origen de la referencia.¡Error! No se encuentra el origen de la referencia.**). The questions on which supplementary tools are needed and for what, is linked to the question if a market platform design can contain all necessary functional building blocks to select the most economically optimal flexibility offers for grid operation, when requested as a service from the system operators view (43). A large set of the identified functional building blocks were found to be required in the CoordiNet demonstrations. In Figure 11**¡Error! No se encuentra el origen de la referencia.** the 14 tools that have been identified are shown. These tools are in the illustration mapped to three levels of functionalities that are required in a market platform and for grid decision tools, (1) monitoring & publication functionalities, (2) matching & settlement functionalities as well as (3) validation and risk management functionalities.

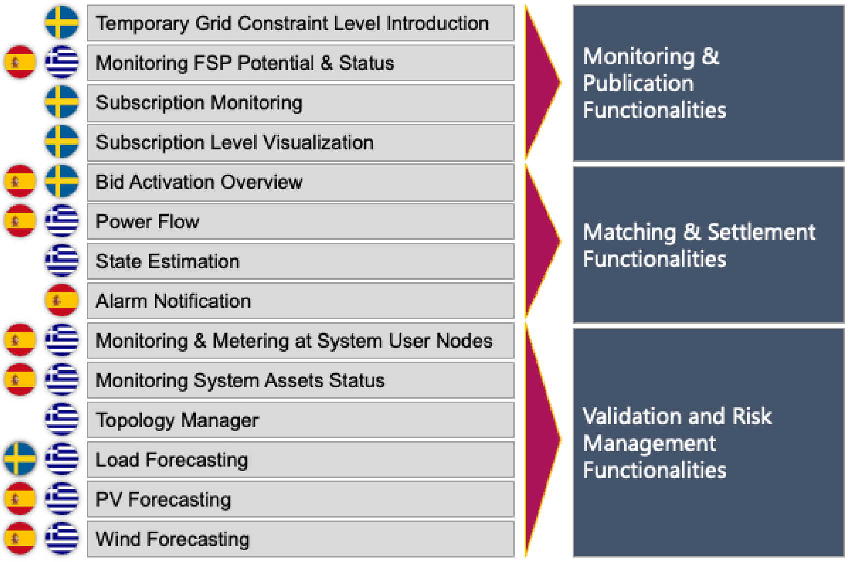


Figure 11. Functionalities and tools for short-term planning tested in the different CoordiNet demonstrations.

Monitoring and publication functionalities are important to be able to get a good visibility of the status of the grid and thereby the publication of flexibility requests, which comes with the need for smart monitoring functionalities. Currently, there is no clear framework for how flexibility needs should be defined which is exacerbated by the lack of secure and accurate tools, long-term forecasts, and guidelines. As stated in (41), these involve more real-time capabilities, in monitoring and network management which for some services would need to be closely related to topological system views to allow for instance voltage profile monitoring. Monitoring can be arranged for different actors in market platforms separately. In particular, visibility for DSOs allows to publish flexibility needs, based on the location of the demand. Here, a use of shared databases containing smart metering data and flexible customers' technical characteristics are still being discussed. Furthermore, the assets or grid status can be presented in an aggregated form. In the example of SmartNet, a tool to aggregate data for the use by the SOs has been developed. The aggregation function allows for exchanging real-time data of the active and reactive power at the distribution level, for instance, with the higher level system operator's SCADA system (44).

Insights from the demos: Sweden

Seasonal and year-to-year variability of flexibility needs has a big impact, as well as posing a significant challenge to attract market participants and achieve market liquidity. For example, the winter of 2019/2020 was very mild in Sweden and the need to purchase flexibility for congestion management was very low. On the other hand, the demonstration on Gotland, Sweden, shows that a major challenge is that the power flow in the HVDC substation can vary drastically on very short timescale (up to 100 MW in just 15-20 minutes) due to the variable wind production. Even a modest cold snap, with just a few minus degrees, can in absence of wind, cause very high loads. Hence, the accuracy of the weather forecast is of great importance.

Considerable improvement in accuracy of the flexibility needs forecast was made during the Coordinet Swedish demo. While the mean error of around 5%, achieved in normal operation, may be a challenge to decrease further it was identified that the accuracy in extreme situation could likely be improved. The target would be to improve the forecast in the following situation: i) rare low temperature events with small amount of previous data for the machine learning algorithms to be trained on and ii) unusual grid configurations when the pre-defined impact factors (power transfer distribution factors determining how various substation power flows are impacted by FSPs) become misleading. Here, a digital twin of the grid could be beneficial.

4.1.4. Roles, responsibilities, and SO coordination

The actors affected most in the context of this new flexibility markets are SOs, the stakeholders who operate the market, and the commercial parties, e.g., FSPs, including the (independent) aggregator, and balancing responsible parties (BRPs). Some of these agents are still not fully implemented in the European and National regulation such as the (independent) aggregators, market platform operators, etc. This section will be focused on the SO roles and responsibility. In the past, roles and responsibilities were clearly distinguished between TSOs and DSOs as they are separated between the different networks. However, as the energy system is currently undergoing a paradigm shift, market stakeholders are required to alter their activities accordingly. For instance, when DERs are activated, the decisions of one SO are most likely influencing the other and thereby increasing the need for coordination (19). However, the way grid constraints are accounted for, highly depends on the responsibilities and roles assigned to the different market players (2). *CoordiNet therefore recommends defining clear roles and responsibilities in new established flexibility markets including both the actual and new agents involved in these processes (Recommendation 1.3). A common EU-level definition of roles and responsibilities should be included in the new network codes for demand side flexibility (Action-Recommendation 1.3).*

Much effort has been made across Member States. A basepoint has been the Harmonised Electricity Market Role Model (HEMRM) initiative of ENTSO-E and the associated organisations EFET and ebIX (45). The aim of this model is to simplify the communication among the market participants from different countries by providing such common taxonomy and vocabulary for actors prevalent within the European electricity market information exchange. The model has further been amended based on inputs from the Bridge initiative and from a number of EU funded projects (46), including the CoordiNet project, mostly focusing on missing roles related to the distribution grid and the market-based procurement of flexibility by DSOs as currently, there is no common taxonomy and vocabulary that could uniquely identify roles, eligible entities, and responsibilities in a flexibility market. What can be highlighted from this analysis made within Bridge, is that some actors have been assigned new responsibilities while, in other cases, the possibility for more actors than one to fill a role have been identified. One of the major differences is the eligible entities that can cover the role of "Data provider". In the original case only the TSOs, or a third-party agreed by TSO, could take that role which was quite limiting considering the market evolution towards flexibility offerings, decentralisation, and increasing active participation of final users. Considering these developments having a highly centralised actor as data provider would be suboptimal. Therefore, the Nominated Electricity Market Operator (NEMO) and DSO should also be allowed to cover this role in addition to the TSO.

To be able to establish and, also in the future, scale-up flexibility markets a common ground and language is important to avoid misunderstanding. *A harmonised nomenclature that provides a full description of relevant roles and those role´s responsibilities should be defined. Such nomenclature should be descriptive of the principles and key characteristics connected to each role, not restricting roles to certain actors. To develop this nomenclature, an impact analysis that evaluates the role attributes is required, taking into consideration that the national context will influence how roles can be implemented (Action – Recommendation 1.3).* Such a nomenclature should be included in the new NC of Demand Side Flexibility on distribution level. Due to the immaturity of these markets, it is unwise to set too strict rules as to what actor should take on what role and task within the flexibility market as the efficiency of different solutions will vary depending on the market design and the regulatory context. For example, the demonstrations in the CoordiNet project have tried different approaches towards the role of market operator and platform/data operator.

In the Swedish and Greek demo, for local congestion management, the DSOs have taken the role of market operator since they are the only buyers in the market (33,40). The Spanish demo has tested a different approach where the market operator in local markets is not the DSO, but an independent third-party (47). Here, it becomes important to consider the context specific conditions in relation to the key characteristics that the role of market operator must fulfil. As long as these key characteristics can be upheld, the market operator role will function efficiently. Some general criteria regarding this role can be made:

- Careful consideration should be taken when deciding on the entity taking on the market operator role and the national context of other markets.
- If a third party act as market operator this could significantly increase the cost and complexity of market operation. To keep CAPEX and OPEX down, it is necessary to keep in mind that increasing the complexity of market operation and grid management by broadening the scope of involved actors increases the cost of operating the grid, and will impact the financial viability of the market.
- The market operator must take into consideration that the TSO and DSO are the responsible agents for the grid security. The methods for bid prioritisation should therefore be determined in cooperation with the Sos to ensure an efficient and secure operation.

Regarding the role of platform/data operator, in Greece, each system operator is its own data manager, but there is an additional platform/data operator role that coordinates all communication between the DSO and TSO. This platform operator role is an independent actor. As in Greece there is only one DSO, the demonstration highlights that a common market platform or a local market with a common actor is necessary to secure the interaction. In the Spanish and Swedish demo the platform/data operator was the same actor as the market operator (33,47). These approaches have their merits and drawbacks. Some general criteria regarding this role can be made:

- Timely information must be provided and be communicated in a secure and transparent way.
- Duplication of costs should be limited, and creating for example separate data hubs for the data management might come with extra costs.
- The data management role could be taken on by the DSO. In the Spanish demo, a data platform commonly owed by serveral DSOs, SIORD, is used.

In general, the main priority of the operators should be the security of the system and ensuring a transparent market operation for all actors included. In this context, for example, if the DSO takes both roles in a common market model, platform and market operator, it could cause transparency issues, as the DSO is not the sole buyer.

4.1.4.1. The new role of DSOs

As mentioned, the role of the DSO is becoming more active and will require a different approach to the planning of day-to-day operations as well as more long-term grid planning. As previously discussed, within the context of neutral market stakeholders, certain interpretations of the future DSO role extend the DSO activities to the coordination or hosting of the flexibility market platform on the distribution grid level, thus being a market operator (48). However, many challenges arose in the process of seamlessly integrating flexibility functionality in the operation context for the DSOs active in the CoordiNet demonstrations, where operators were unfamiliar with making DA decisions, or even ID, and lack data, routines, and systems for such new paradigms. *To enable DSOs to work proactively and mitigate structural congetion, complementing current near real-time operational practices with longer procurement horizons, NRAs should consider flexibility procurement in their guidelines for the Network Development Plan (Action – Recommendation 1.1). In addition, to be able to work with the new responsibilities that come with the new operational model, internal education programs are necessary for the personnel to cope with the new challenges (Action- Recommendation 1.4)*.

Through the set-up and operation of a flexibility market for congestion management, the DSOs in the demonstrations have shown abilities needed to include the procurement of flexibility which differs from a traditional more passive DSO role. The main differences of the new and traditional DSO role are summarised in Table 5.

Table 5. Characteristic changes in the role of the distribution system operator. Illustration sourced from CoordiNet deliverable 4.5 (49).

	Traditional DSO	DSO using flexibility	
	Resource oriented / Network focus	System focus	
	Producers and consumers	Producers, consumers and prosumers	
	Investments	Investments and Flexibility	
	Metering energy consumption	Metering energy flow, monitoring grid status and DER data, also provided by aggregators	

Insights from the demonstrations: Sweden

The demonstration of the flexibility market in Sweden formed the starting point of a cultural change in the mindset of the operators, who are used to work in a rather reactive and real time manner. DSO operation has acted on forecasts for the first time, buying flex to avoid congestion. The platform and market design enable and even force the operators to think and act more proactively.

The idea was that a designated operator of the day would log on to the platform every morning to see the forecast for the next day and make decisions if flexibility was needed or not. It is questioned if the operators should be making the decision to activate flexibility or if new back-office functions should be created for this. These new people would still have to coordinate with grid operators, share forecast information and be well informed of contingency plans and reserve power feed contingency options that affect market volumes. They could, on the other hand, be better trained to abide to market rules and be more attentive to FSP constrains and preferences within their approach to activation of capacity.

Using flexibility as an alternative to traditional network planning is controversial for a DSO given the inherent uncertainties of a market-based approach. Will capacity really be available when most needed? How will volumes develop over time? Experience from the demonstration is that energy-only compensation (i.e., paid for only delivered MWh) was insufficient and the variation in demand and hence cleared volumes from year to year require capacity compensation to achieve sufficient market liquidity.

New responsibilities of DSOs include upholding and coordinating system security, deploying new equipment for metering, and introducing flexibility agreements to flexible system users. Other include data management, implementation of an energy information system and a data hub, roll out of modern and intelligent measurement equipment. These are all components of the data manager role. The current lack of data and analytical capabilities to analyse and interpret data and control the system configuration, together with inadequate information or operational technology systems, are seen as some of the key barriers DSOs need to overcome (48).

Flexibility markets will necessitate a shift in DSO operation and come with changes in regulation and new responsibilities for the DSO (Recommendation 1.4). With the change in ways that the DSO operates the grid, including flexibility service procurement, the DSO must change to a more system-based approach instead of today's asset-based approach shifting the focus from asset management to FSPs and what services they can provide (Action- Recommendation 1.4). This shift in approach would be better suited to support an increased liquidity to ensure that flexibility exists when and where the DSO needs it. Solely building up the business model around economies of scale will not suffice as incentive for establishing flexibility markets. The factors around which the focus of the new business model's should be established are "(1) resource-driven, (2) offer-driven, (3) customer-driven, and (4) finance-driven" (50). Furthermore, the DSO will be required to continuously ensure technology neutrality throughout the implementation process of an active system management vision. Stakeholders seem to support the role of DSOs as the neutral market facilitator (51–53). Foreseeing a customer centric energy system, DSOs are in the position to act as network energy market facilitator. Different objectives drive the task of active coordination between all market participants, facilitating products and services in a neutral and non-discriminatory manner (54).

4.1.4.2. SO coordinated procurement of flexibility

ENTSO-E suggests that each SO (and not only the connecting SO) has direct access to DERs, both technically (direct activation path) and contractually (direct bid submission and settlement) (55). *For a future efficient use of the electricity grid, coordination between SOs is key for a seamless operation over voltage levels. Higher coordination will help limit the negative effect and consequences flexibility procurement might have on other voltage levels and in the long-term enable flexibility markets to scale up (Recommendation 1.5).* Different coordination schemes will require different levels of coordination between TSO-DSO and certain interoperability levels need to be established between the markets. In deliverable D6.4, it was found that various countries in the EU already have TSO-DSO coordination in most timeframes of operational planning and real-time operation of the system which will be further intensified in the future (21).

SO-coordination is also important for sharing the flexibility activation cost between the involved SOs when the same FSP provide added value to several SOs together. Activated bids may affect other levels of the system, for example by triggering the need for flexibility products to be procured by other SOs to manage their grid. How to split the bill between system operators can become an issue as the complexity of tracing back each service's cause, effect, and cost increase. *Hence, although roles and responsibilities should be clear, a set of best practices of cost allocation methods between SOs, when different SOs procure their flexibility in a joint (common) market or when procuring flexibility that affected another voltage level, should be gathered. This should be included in the future regulatory framework approved by the NRA (Action-Recommendation 1.5).*

4.1.4.2.1. Coordination schemes for efficient SO coordination

In CoordiNet deliverable D6.2, properties of the different coordination schemes seen in Figure 12, and a large span of variations of these schemes, have been analysed. In the analysis a variety of criterias have been included. The primary focus of the analysis of coordination schemes was on the efficiency of the procurement process but other criterias was included, such as: (1) the optimality of the procurement process under different TSO-DSO coordination schemes, (2) the technical and financial barriers to entry in each market design when considering flexibility resources with different technical characteristics, (3) different product specifications and harmonisation challenges, (4) adequacy of each market design in meeting specific needs depending on the national grid characteristics, among others (21).

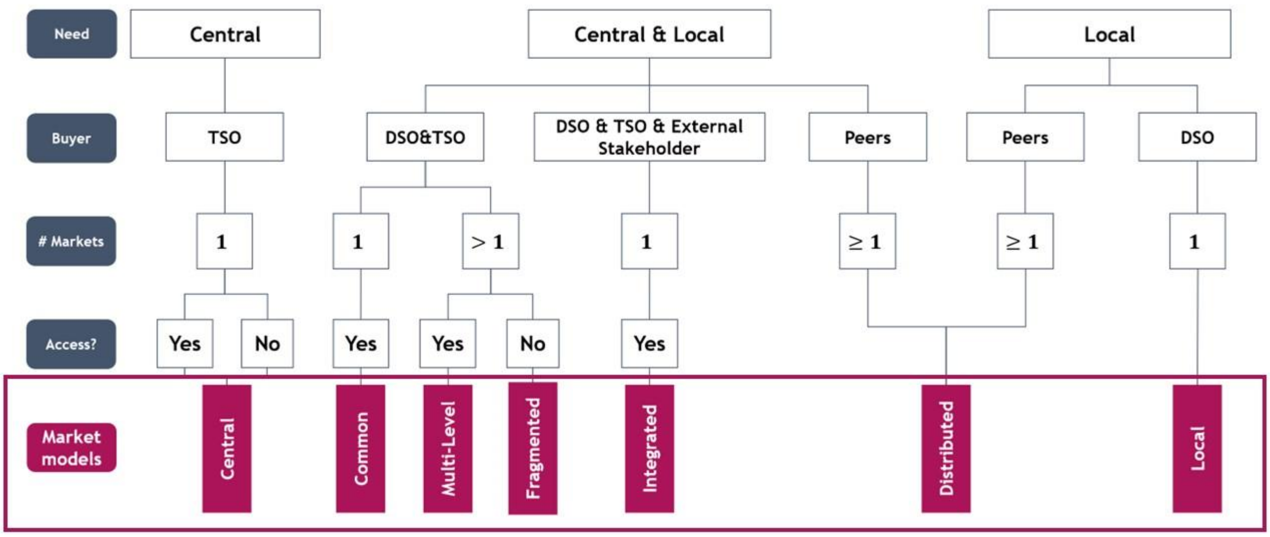


Figure 12. Properties of the different coordination schemes evaluatedn the deliverable D6.2 (21).

Deliverable 6.2, finds that under certain conditions the common market will be the most efficient and least costly market model (from a procurement cost perspective) and that it would in general achieve the highest social welfare[5] by improving overall system efficiency (21). This finding is based on an evaluation of the efficiency of the market, i.e., where optimal utilisation of DERs is achieved, the coordination efforts are low, and interoperability challenges are reduced. In the D6.2 analysis, the common market is found to be most efficient since the market clearing process make use of a pool of available flexibility resources (i.e., the submitted bids from all voltage levels) to meet system needs of all SOs while simultaneously taking operational requirements of the grid into account. However, the optimisation algorithm in a common market may require a significantly longer computational time as it will have to take into account a larger set of needs set by buyers to match with a larger set of FSPs with varying capabilities and bids, as well as the complexity of the network representation (number of nodes, connecting equipment, lines, etc.). In addition, a common market, where both TSOs and DSOs act as buyers, has higher requirements in terms of activation time, minimum bid size, communications, etc. which can be a barrier for some small resources, particularly those connected to the lower voltage levels. However, if requirements for participation is harmonised to allow small-scale resources to participate in a common market – a natural incentive to cooperate could be created as cooperation would guarantee access to needed flexibility in the most optimal manner (21).

Conclusions from the demonstrations also highlight that a common market, where the TSO could access resources in the DSO grid, would increase complexity and could be a disadvantage for the DSO. In a separate market, it is possible to reduce the complexity (or, alternatively, the computational time) of individual optimisation algorithms, which can also be adapted to optimise for specific requirements. Separate markets would on the other hand not be able to reach the same level of efficiency of flexibility procurement as the common market. In a common market it would be possible to capture the value of flexibility meeting the needs of different SOs simultaneously. Separate markets would necessitate development of ways to coordinate procurement between system operators to manage potential impacts of market results, something that could present significant challenges (56).

In practice, however, the choice of one scheme over the other will be governed and impacted by many different aspects discussed in this deliverable, such as (i) procurement of capacity vs energy, (ii) timing aspects and (iii) market-clearing, (iv) information sharing, (v) technical product or service requirements etc. The full exploration of these comparison dimensions can be find in deliverable D6.2 (21) *Therefore, in the early stage of development of flexibility markets, to establish liquidity and attract FSPs, simple market schemes are recommended. With time, more complex approaches to market coordination mechanisms, where both DSO and TSO have access to the same market, might be recommended to explore, as it could be more efficient (Recommendation 1.6).* It is worth mentioning, that a comparison focused only on separate vs common market flexibility procurement in an isolated fashion is a simplified evaluation. Project findings highlight that under certain conditions, when the interface flows are optimally priced for example, the efficiency of the fragmented and multi-level approaches could converge to the most efficient common market (21). For a more detailed analysis, the CoordiNet deliverable D6.2 presents an extended classification analysis, and comparison of coordination schemes.

4.1.4.2.2. Hierarchy and sequence of different markets

To coordinate the interface between SOs, operating on the same or separate markets, the hierarchy between markets and actors is in need of further specification. This goes beyond the previously mentioned definition of roles and their responsibilities in a market. Hierarchy between actors and markets more strongly connects to prioritisation of the flexibility need between SOs and how the flexibility procurement might also have effect on other voltage levels than the one the asset is connected to. It will therefore also

[5] In this context, "social welfare" is used to describe the maximizing of surplus for both buyers and sellers.

impact the ways in which coordination schemes will function. At present, there is no such framework, which has been identified as a barrier for flexibility market implementation in the CoordiNet project. For example, several SOs might request flexibility at the same time without clear rules for which needs has priority to be matched first to be able to ensure grid security and stability or to manage congestion. As the set-up of SOs and market actors differs between Member States, the hierarchy order might differ between countries. For example, in Sweden, the Swedish power grid is structured in a way so that several DSOs could operate in the same geographical area, but at different voltage levels in the distribution network. *It is therefore of importance that the hierarchy between market actors is clearly defined and established taking the national specific structure into account. However, the SO where the FSP is connected to should have a priority as it is their responsible to ensure the grid security criteria in their grids and to provide quality of supply to all customers (Action-Recommendation 1.3).* In the literature there are opinions both supporting the need for DSO markets to be cleared first, before the TSO markets, and vice versa. In the case of separate flexibility markets, several authors have proposed sequential market designs, in which one SO clears their market first and forwards unused bids to the following market (19,57,58). The timing aspect and sequence of the markets applied in the CoordiNet project will be discussed more in detail in theme 4.

4.1.4.3. Requirements for information sharing

To guarantee that network issues will not be caused, information sharing among system operators (or with third party market operators) may be required. In the context of the different options of coordination schemes, The TSOs and DSOs need to agree, under the applicable national framework, on a common process for information exchange to ensure system security and enable the participation of flexible resources from all grid connection levels (59). Depending on the coordination scheme, high amounts and different types of information would need to be shared between SOs which could lead to replication of sensitive data. Furthermore, as indicated by Smartnet, coordination can take place across different market phases (prequalification, procurement, activation, and settlement) and depending on the phase in which coordination takes place, different mechanisms might need to be set up to ensure the required data exchange for coordination takes place (2,60,61). This will be discussed in more detail in Theme 4.

Currently, the SOGL and the Key Organisational Requirements, Roles and Responsibilities (KORRR) guideline regulates the requirement of grid observability and data access between TSOs and DSOs for already established market. For flexibility markets for DSOs however, there is no general agreement at European level on requirements. In general, for coordination schemes that enable the SOs to access flexibility resources outside their areas of control, network considerations of all involved grids should be included in the market clearing process to avoid constraints violations (this will be discussed in Theme 4). Hence, the level of required information sharing would differ between different market models and coordination schemes. For instance, the fragmented market model does not require information sharing between the system operators, as each of them can access only the flexibility resources within its area of control. On the other hand, the multilevel market model allows the TSO to procure services from the flexible resources connected to the distribution system and thus information sharing between the TSO and DSO is vital. In that case, the TSO should not only take into account the constraints of the transmission system, but also the distribution system, to avoid causing operation issues in the distribution system. This raises the question on what data sharing processes between DSOs and TSOs can be followed to give as much relevant information as possible about the distribution grid to the TSO (or to a third-party market operator) while keeping a high level of confidentiality regarding the distribution systems and a low practical need for replicating grid data in different systems (21). In general, to prevent the need for exchanging sensitive information directly between system operators in the market design, requiring such network information sharing (e.g., the common, central, and multilevel markets, etc.), the market can be run by a third party (e.g., market operator). However, this requires a higher amount of data exchange, as TSOs and DSOs must send the information to the third party.

4.1.5. Theme 1 Recommendations

Table 6. Theme 1 recommendations and list of actions derived from the CoordiNet demonstrations and analyses.

Recommendations	Actions	Level of implementation	Priority
1.1 Regulatory revision is required to assure adequate support and incentives for DSOs to establish flexibility market mechanisms.	Integration of the CEP in national regulation in each member state. Implementing article 32 of the Energy Directive, as well as all relevant articles to enable the procurement and use of flexibility in the distribution and transmission system.	National	High (defined in CEP)
	New network codes for demand side flexibility on distribution level are already under discussion. These should comprise common EU-level principles on how to design and operate flexibility markets including clarification of the relation between flexibility markets and non-firm connection contracts, considerations for new actors, the definition of how flexibility needs are to be quantified and provide guidelines on which product to use when, etc. However, most of the details should be discussed and decided at national level.	EU & National	High
	The procurement of local flexibility services requires to update the economic regulation of the DSOs to consider the cost of implementing and using flexibility markets and to provide economic incentives to purchase flexibility. The overall cost-efficiency must be optimised against a long-term perspective, with the aim of society wide electrification, which could result in short-term cost inefficiency. Other DSO capabilities such as increasing grid connections or grid efficiency could be incentivised via the remuneration scheme in a transitional period.	National	High
	Grid tariffs should be revised, if not already designed to, to coordinate the implicit flexibility and the explicit flexibility.	National	Medium
	To enable DSOs to work proactively and mitigate structural congestion, complementing current near real-time operational practices with longer procurement horizons, NRAs should consider flexibility procurement in their guidelines for the Network Development Plan.	National	High
	Potential impacts of the future flexibility markets on already established markets (balancing or re-dispatching) should be evaluated as these might require the amendment of some Network Codes, such as the Capacity Allocation and Congestion Management Network Code, System Operation Guideline or the Balancing Guideline.	EU & National	High

1.2 National regulatory authorities and public institutions must take a larger role and more responsibilities in supporting implementation of flexibility services.	The benefits of flexibility solutions have society-wide effects and public institutions could play a more active role in promoting both flexibility and efficiency solutions. Clear and reliable information from third party actors should be promoted for FSPs and the broader public regarding the flexibility markets, including relevant information on the products for system services.	National	High
	By providing funds for R&D pilots the financial burdens of implementation of flexibility solutions could be lowered.	EU & National	Medium
	Regulatory sandboxes could be an efficient way to provide an evidence base for regulatory bodies to determine what regulatory updates are needed to fit with current and future market formations.	National	High
1.3 Define clear roles and responsibilities in new established flexibility markets.	A harmonised nomenclature that provides a full description of relevant roles and those role´s responsibilities. Such nomenclature should be descriptive of the principles and key characteristics connected to each role, not restricting roles to certain actors. To develop this nomenclature, an impact analysis that evaluates the role attributes is required, taking into consideration that the national context will influence how roles can be implemented.	EU	High
	A common EU-level definition of roles and responsibilities should be included in the new network codes for demand side flexibility.	EU	High
	The hierarchy between market actors is clearly defined and established taking the national context into consideration. However, the SO where the FSP is connected to should have a priority as it is their responsible to ensure the grid security criteria in their grids and to provide quality of supply to all customers	National	High
1.4 Flexibility markets will necessitate a shift in DSO operation and come with changes in regulation and new responsibilities for the DSO.	With the change in ways that the DSO operates the grid, including flexibility service procurement, the DSO must change to a more system-based approach instead of today's asset-based approach shifting the focus from asset management to FSPs and what services they can provide.	National	High
	Improving the operational model for the DSO, utilizing the grid more efficiently, also comes with the need to work more proactive. To secure liquidity in flexibility markets, the DSO should work with longer operational planning horizons and put more effort on forecasting models and tools. The grid planning at the distribution level should be coordinated with the grid planning at the transmission level. Finally, a holistic approach should be considered to consider other energy carriers, such as hydrogen.	National	Medium

	For the operators of the DSOs to work with the new responsibilities that come with the new operational model, internal education programs are necessary for the personnel to cope with the new challenges.	National	Low
1.5 For a future efficient use of the electricity grid, coordination between SOs is key for a seamless operation over voltage levels. Higher coordination will help limiting the negative effect and consequences flexibility procurement might have on other voltage levels and in the longer term enable flexibility markets to scale up.	A set of best practices of cost allocation methods between SOs, when different SOs procure their flexibility in a joint (common) market or when procuring flexibility also affecting another voltage level than the one the asset providing the service is connected to, should be gathered. This should be included in the future regulatory framework approved by the NRA.	EU & National	Medium
	To correctly evaluate grid status, performing operational planning and monitoring, a common approach to communication between SOs should be developed to enable the emerging information needs for the establishment of flexibility markets.	EU	Medium
1.6 In the early stage of development of flexibility markets, to establish liquidity and attract FSPs, simple market schemes are recommended. With time, more complex approaches to market coordination mechanisms, where both DSO and TSO have access to the same market, might be recommended to explore, as it could be more efficient.		National	High

* Business
Techno-economic
Institutional and regulatory
"Social"

4.2. Theme 2: Market access for all flexibility service providers

The Challenge: The previously one-directional electricity supply is becoming more dynamic and flows of electricity are changing as new grid service providers are emerging. These new market participants do however face market entry barriers that need to be addressed to attract the substantial flexibility volumes and capacity necessary to achieve system level impact.

Key take-aways from the Coordinet experience:

Viability of the flexibility service provision business case
The CoordiNet findings stress the need to find ways of improving the FSPs business case. Currently, high costs for FSPs to manage their market participation reduces their margins of profit significantly. FSPs participating in the CoordiNet demonstrations requested suggested that support for higher degrees of automation could help increase participation in the markets. Likewise, insecurities regarding return on investment for market participation is exacerbated by the differences in flexibility demand between seasons/year-to-year. This variability makes it difficult to attract FSPs as their supply would create profits with high variability across time. In the CoordiNet demonstrations clear communication, from SOs on how much flexibility is needed and when it will be needed, was implemented to help mitigate insecurities caused by the variability of demand. To further reduce the economic uncertainties and provide a higher degree of predictability of income regarding the potential business case of FSPs, market prices must accurately and transparently represent the value of the service which is affected by the location of the resources in the grid and its availability in time.

Ensuring access and setting transparent rules for participation for all market actors
For all potential service providers to access these markets, thereby securing the necessary volume of flexibility, regulatory overview will be necessary as the scalability and replicability analysis of the CoordiNet demonstrations showed, regulatory barriers are still significant for DERs of a broader span of sizes and technologies to participate in the markets tested in the project.

The independent aggregator
For small-scale resources to cope with the technical requirements of the markets, one solution is aggregation. The concept of independent aggregation is formalized in the CEP, but full implementation is taking time. Ensuring the introduction and regulatory support for this actor will play a key role in enabling the participation of small DER in future flexibility service provision and implementation of rules and frameworks for how this actor can interact in the markets should be a priority in all Member States. For example, it is not defined how the effects of the independent aggregator’s market activities, on energy suppliers and balancing responsible parties, should be corrected and each Member State could implement different approaches.

Consumer awareness and perceptions
Currently, there is low level of awareness and understanding of grid related issues and potentials for flexibility service provision. Providing clear and reliable information for FSPs on how to access markets via user friendly and well-designed platforms and interfaces will be important to bridge information gaps on market opportunities. Clear and transparent provision of information regarding potential for market participation will be important to help new market participants and utility customers understand their electricity consumption profile and what their flexibility is worth across markets and across time. For many FSPs participating in the CoordiNet demonstrations the trials provided an important and valuable learning opportunity which will continue to add value to future market implementations. Providing opportunities for learning will be important to lower the threshold for participation, especially for those actors where flexibility provision lies far away from their core business.

As previously discussed, the electricity market has traditionally been characterised by passive consumers for whom flexibility markets and TSO balancing markets are not naturally top of mind. However, faced with volatile energy prices on the world market, European industries and consumers are spending an increasing share of their resources on energy. Coupled with a growing awareness of the need for large-scale integration of RES and electrification to reach climate targets, the consumers role in the value creation process is becoming more evident and present in the public debate.

Improving TSO-DSO-consumer cooperation and the development of platforms to enable this has been one of the main goals for the project with the ambition to support long-term aims to allow all market participants to provide energy services. This would open new revenue streams and benefits for consumers that are providing the system services. However, to achieve system level impact, substantial flexibility volumes and capacity from these new market actors will be necessary to meet the growing demand for flexibility. Barriers exist for developing a convincing business case as regulations and markets are currently set up to support traditional functions and actors. Without well-designed and dynamic regulation, rules for existing market participants could become unintentional obstacles for new entrants. The CoordiNet project has provided insights to understand different types of FSPs and DER where the real market demonstrations mainly focused on the local provision of congestion management, thus FSP feedback centres around this service. Real world demonstrations are complemented by implementing and testing market platforms where FSPs were able to participate in trials. In the following, we will look closer at factors that impact FSP participation and how stimulants and incentives can be created to address some of these barriers.

4.2.1. Who are these new actors?

New market actors include a broad selection of electricity consumers. FSPs, the agents providing flexibility services, may represent flexibility connected to the distribution or to the transmission grids. FSPs can be a direct owner of flexible resources, which participates in the provision of system services, an intermediary such as an (independent) aggregator, or a retailer that represents flexible resources and coordinates their response. Therefore, flexible resources can include both DER and centralised resources connected to the transmission network. *The CEP states that DERs should be able to participate with flexibility, but EU requirements should be revised to make sure to include different types of technologies such as generators, storage, and demand. It is important that regulatory barriers are removed to enable all types of FSPs to participate in the markets on equal terms (Recommendation 2.1).* FSPs engaged in the CoordiNet project highlighted that a clear regulatory framework for participation in the markets would improve their willingness to provide flexibility as they were faced with uncertainties regarding the formalities and possibilities of their engagement. *In addition, as the CEP is implemented, already existing national regulatory frameworks for active balancing markets should be revised to ensure technology neutrality also in these markets (Action-Recommendation 2.1).*

Defining a clear-cut segmentation of FSPs is challenging as differences in for example market models, network regulations among countries, and differences in consumer needs and capabilities complicate the development of a standardised criteria for segmentation (62). However, there are some repeated characteristics expressed by the CoordiNet partners and a segmentation was thus developed to support the recruitment and customer engagement process when setting up the CoordiNet demonstrations. These relate to assets owned based segmentation, e.g., owners of electrical vehicles, storage heaters, electrical heat pumps, CC-technology, RES etc., and segmentation based on the character of consumption, large, small, commercial, or industrial. In the CoordiNet project the segmentation of potential FSPs has therefore been done in accordance with Table 7 to make it possible to create a structured approach to customer engagement and identification of potential participants.

Table 7. FSP segmentation applied in the CoordiNet project. Sourced from CoordiNet deliverable **(62)**.

Type of consumer	Categories	Examples of Resources	CoordiNet demo
Large-medium size consumers	Industrial processes	Basic materials production Industrial heating and cooling application Manufacturing Waste and water treatment	Spanish, Swedish
	Backup power	Hospitals Power utilities Military bases Telecom base stations	Greek, Swedish
	High tech	Data centres Laboratories	N/A
Large organisations or power companies	Property owners	Shopping centres Sports facilities Office buildings Public housing Public buildings Apartment buildings Schools Nursing homes Hotels	Swedish, Spanish
	Transportation	Public transport Railway EV charging in parking garage	Swedish, Spanish
	Renewable energy sources	Wind power farm PV park	Spanish, Swedish, Greek
	Power generators	Resources connected at transmission and distribution networks	Swedish
Aggregated small consumers	Electrical Appliances	Grocery stores Bakeries Dry cleaners	N/A
	Heating or cooling	Single family homes Condominiums	Swedish (through aggregation)

Findings presented in previous CoordiNet deliverables emphasise the importance of technological capability as well as knowledge and experience with flexibility services to enable successful recruitment (62). Therefore, it was strongly recommended that larger size, in terms of electricity consumption, and technology should be the prioritised consumer segmentation for defining which FSPs to involve in the project. Findings presented from the project are therefore concentrated to a segment of FSPs that are capable of providing larger shares of flexibility. For consumer engagement, beyond these and other R&D demonstrations, there should of course be no need for prioritising any segment or technology as implementation should be technology neutral and markets open to access. Realistically speaking large-scale actors will provide the bulk of flexibility demand. However, significant necessary sources of system flexibility will be needed from aggregated small-scale customers and communities. The role of aggregators, a novel function in the current system in many Member States, has therefore also been given significant attention in the development of market and flexibility platforms and in the analysis in the Roadmap.

4.2.2. Awareness and capacity to participate in flexibility markets

There is currently a vast gap in knowledge and research where the consumers perspective is at the forefront and focus of study when evaluating the effectiveness and function of market-based procurement of system services. As analysed by the Swedish Energy Market Inspectorate, customers today often do not know about the potential of their flexibility and also lack the necessary technical equipment (63). *Low level of* *awareness and understanding of grid related issues and potentials for flexibility service provision will be an important barrier to tackle to increase market participation. Clear and reliable information for FSPs (including independent aggregators) on how to access markets, as well as transparent processes for FSPs to gain trust in the market should be promoted (Recommendation 2.5).* A part of this is to ensure that new market participants and utility customers understand their electricity consumption profile and what their flexibility is worth across markets and across time. *Here the design of user friendly and well-designed platforms and interfaces will be important to bridge information and knowledge gaps that might deter actors from participating (Action-Recommendation 2.5).* Consumer tools showing grid operation in local systems and the benefits or impacts on the transmission system should be prioritised to facilitate this transfer of knowledge and empower consumers to make informed decisions. Consumer's acceptance of potential impacts on comfort levels or the perceived ease of use and integration in everyday life/operations will have significant impact on flexibility service implementation. Increased understanding of the benefits provided to the system and society, as well as empowerment of consumers to take control over their energy consumption, while profiting from it, will make it easier to mitigate any potential impacts that consumers would experience as negative.

Overall, the FSPs engaged in the CoordiNet demonstrations had limited knowledge about products traded in flexibility markets and information campaigns for flexibility markets and products have not been sufficient (64). There are currently not enough resources dedicated to understanding and communicating the benefits and economic advantages of providing flexibility. In Spain, it became particularly difficult to involve commercial actors that lacked energy experts that could evaluate the technical capabilities of the installations to provide system services. A similar situation was found in Sweden where one of the main barriers for participation was the time investment needed to understand the processes involved, to coordinate with external partners, and other aspects of similar nature. Even DER resources of larger scale, that have an easier task to map their own processes, load curves, and flexibility specifications, are under current market-design not incentivised to be energy market experts. *The development of tools to help FSPs evaluate their potential for flexibility provision and provide guidelines for how they can start engaging in flexibility markets would be of great use (Action-Recommendation 2.5).* This is also necessary for FSPs to be able to make proper risk evaluations of how market participation might interfere with their normal production/load curve.

Insights from the demos: Sweden

To mitigate the initial learning curve, FSPs highlighted the importance of providing an overall picture of market calls for flexibility. Some FSPs expressed a need to get more information on the total calls for flexibility from the local market to understand and learn more about how the market works.

In general, having efficient, transparent, and well-remunerated markets act as main drivers for the increased inclusion of flexibility resources in the electricity system and in flexibility markets (62). *Rules should ensure transparency in flexibility market operation and bid selection processes to increase the confidence and interest of FSPs, including independent aggregators, in emerging business cases.* For example, i*nformation about potential business opportunities for FSPs should be made more easily accessible, for instance trough National or regional calls for flexibility services which could be announced on an open portal (Action-Recommendation 2.5).* Drivers for large scale actors to participate in CoordiNet demonstrations have, however, not solely been dependent on financial gain or technological capacities. In the Swedish demonstrations, many FSPs mentioned goodwill or PR as important drivers and expressed a desire to improve their image towards their customers, the DSO, and different authorities. Furthermore, several FSPs considered the Swedish demonstration as an educational opportunity. Both regarding the market and their own business operations where the potential of exploring how their technology can be used more efficiently or in completely new ways was an important driver (65). Providing such learning experiences will be important to lower the threshold for participation, especially for those actors where flexibility provision is far away from their core business. Another driver mentioned by the Swedish FSPs is that many FSPs, and more specifically industrial FSPs, consider local grid congestion as a potential limitation to their future growth. Meaning that knowledge about the local context provided these actors with the motivation to proactively mitigate future risks for their company by participating in the flexibility market. The near-term economic benefit of market participation was not the main strategy but rather to ensure growth long-term. Needless to say, economic benefits of market participation are of course a significant driver, and the exploration of new business opportunities was an important aspect for several participating FSPs. Especially FSPs with reserve power saw potential in obtaining economic benefits from resources they otherwise would rarely use. However, such considerations were not the only motivations in the context of the CoordiNet demonstrations.

With this in mind, the additional non-economic motivations for FSP participation in flexibility markets should therefore not be underestimated. In this regard, experiences from the demonstrations show that regional authorities and municipalities, which are already experiencing capacity constraints, have natural incentives to bring innovative solutions and development to their region or city. These actors could become an important steppingstone for incorporating not only larger resources such as public schools and hospitals, but also for spreading awareness through knowledge and information campaigns within the region, as mentioned in Theme 1. The CoordiNet experience has shown that stimulants and incentives beyond a business case is vital to unlock flexibility, since market based ancillary services would seldom be a core business for all possible FSPs (65).

Insights from the demos: Spain

An FSP in Spain mentioned that although the participation in a flexibility market is technically and conceptually complex for entities that do not have energy as their core business, any action that entails economic and/or environmental savings is worthy of analysing.

An additional factor that could impact the rate of consumer participation is the consumers perception of the SOs. SOs, being natural monopolies, would need to pay attention to bridge the gap to the consumers and avoid potential transparency issues. When interviewing FSPs at the end of the project, evidence of where perception of the DSO impacted their view of the participation. In one of the Swedish demonstration sites FSPs displayed distrust towards the flexibility buyer regarding what bids were called, especially at the highest price levels. The suspicion was that some resources could be favoured over others, and that the buyer would choose the resources that they know and understand. Of similar nature, but with a different expression, there will be need to build trust in the novelty of third-parties operating a DER owned by a flexible grid user. In some countries these aspects will play a smaller role and in some it might have a significant impact. This could be mitigated by a larger commitment from NRAs and public institutions in information campaigns and development of regulatory frameworks to build trust, as recommended in Theme 1.

Previous studies and reports provide additional evidence of instances where public perception of the electricity market impacted their willingness to participate. Torstensson & Wallin found that consumers perceived their position in the market as weak and that their confidence in the market operation was low (66). Meaning that the consumers did not have trust that the market operated in a correct and fair way. A Finnish study produced similar results as consumers responded that they perceived an uneven and unfair distribution of profit between energy companies and the consumers (67). The same study found a general lack of trust in corporate actors and the credibility of their value proposition, which will prove of varying importance throughout Europe. Greater transparency in the market will thus also be an important factor in mitigating such tendencies and increase trust in the market function. Some suggestions from participating FSPs included making clear in the market platform which bids had been cleared or to display the total amount of flexibility available in the market. This need for increased transparency was also raised in Spain.

Subsequently, rules should ensure transparency in flexibility market operation and bid selection processes to increase the confidence and interest of FSPs, including independent aggregators, in emerging business use cases (Recommendation 2.5).

4.2.3. Increasing the viability of flexibility service provider´s business case

Ensuring a viable business case is of course a key criterion for FSPs to participate in flexibility markets (Recommendation 2.4). As we will explore further in this chapter, markets for system services are still to be considered a niche and immature market development and the FSPs' business case is in some cases not sufficient on its own to propel the development and large-scale implementation. Currently financial benefits often do not correspond to equipment costs or the increase in human resources needed by FSPs to manage their market participation which reduces their margins of profit. *National regulation should be revised to ensure that proper support and incentives are provided for FSPs to provide flexibility services. For example, incentives for consumers to provide their electric vehicles as a flexible resource could be one such measure to explore further. For small units, specific subsidies, to cover up-front investments, might be necessary to help them reach a viable business case in the early stages of flexibility market implementation (Action-Recommendation 2.4).* In the CoordiNet project, cascading funds were an important factor for the engagement of FSPs to cover the necessary investments to enable their participation. This was specifically highlighted by the Spanish demonstration as the most important incentive, at least for FSPs that where external and not project partners (i.e., needed to install and upgrade their equipment).

Once FSPs have joined the market additional factors should be considered to increase the viability of their business case. *To incentivise small scale actors, with limited in-house resources for managing market engagement, an automatic process and activation of bids could reduce the time needed to participate in the market (Action-Recommendation 2.4).* In the Piclo flexibility tool, both publication and matching of active assets is integrated with demand for flexibility as it is published by the SO (68). This would create ongoing opportunities for FSPs to be leveraged with minimum impact on their own portfolio management. In Sweden a similar approach was suggested by FSPs that said that automation could increase participation in the markets. The automation suggested would imply a continuous and systematic process for bidding and calling that would not require manual handling and would allow FSPs, that qualified assets in multiple locations, to reduce time spent on bid specifications. However, for large scale actors with in-house expertise, loss of opportunity to adjust bids between market sessions could on the other hand negatively impact their market participation.

4.2.3.1. Stacking value across markets

In addition, enabling FSPs to participate in several markets, and implement value stacking strategies to improve their economic efficiency and their return of investment is important (Action-Recommendation 2.5). Making it easier for FSPs to stack value across markets is an important factor for FSPs and can increase the liquidity on the market and thus also benefit SOs. However, current requirements from the TSO for balancing products can be difficult to meet, especially for smaller FSPs and aggregators. Attributes such as the minimum bid size, 1MW in most European countries, and activation time are potentially not technically feasible, excluding them from participation in these markets. Requirements on large-scale markets will have to be surveyed to make sure that market entry requirements are inclusive to also enable the participation of small-scale resources. Likewise, interoperability between market platforms, alignment of prequalification processes that would result in prequalification across several products, and choice of market design, etc will impact the FSPs ability to value stack across markets and take full advantage of potential revenues.

Insights from the demos: Spain

The successful verification of technical capabilities of the FSP CEMEX's demand unit, a producer of building materials of which mainly cement, to meet the requirements of the balancing market represented a significant achievement in the Spanish demonstration. This is not only because it shows the potential of these FSPs, but also because it opens the door to the full participation of this new type of technology in balancing markets, which could have a positive impact on the energy transition. However, today only generation and pumping storage can participate in these markets. More on this topic in Theme 3.

Without aligning market processes and increasing automation between market platforms, FSPs would need to factor in that the different markets behave in different ways to solve the optimisation problem of market participation (21). Most often, DA works as a pay-as-cleared auction system that takes place at noon on D-1 and only allows a single participation. Contrarily, ID is typically a continuous market closing some minutes or hours before delivery, allowing more than one participation that are separated in time. Finally, real-time markets are structured in even more complex ways, sometimes as energy only or as auctions including some capacity components. Lastly, balancing markets (of which in most European countries are DA capacity auctions for FCR, aFRR and mFRR) provide a last-resort opportunity to value flexibility. Due to this, and unfortunately, when making a decision, the FSP does not have the full pricing information.

Many FSPs participating in the Swedish demo stated that they technically could participate in both the DA and the ID market, while others stated that they would need to automatise processes and routines to participate ID. The latter is especially the case for FSPs with back-up generation. Energy companies, back-up generation, and industry FSPs state that most of their resources can only participate day-ahead. Other flexibility providers prefer to provide flexibility closer to delivery time, e.g., aggregators or energy storage. In addition, some assets have long start-up time, some assets do not have automatic steering but are instead manually activated, while yet other assets are part of a planned optimisation and therefore must consider different priorities. It is of high importance that considerations are made in regard to the varied characteristics and capabilities of new market entrants when setting up new markets and defining products. More on this topic in Theme 4.

4.2.3.2. Securing sufficient remuneration for flexibility provision

Experiences from Greece highlight a reluctance, especially from industrial and commercial consumers, to install new monitoring and measurement equipment due to the resulting up-front investment. This points to the need to ensure that investment costs can be recuperated on the market, that the complexity of market participation is reduced, lowering time spent, and that flexibility is sufficiently remunerated. As in any market, market participants act strategically: choosing their actions, e.g., entering a competition, setting bids, etc., based on their subjective evaluation of likely events, determined by for example market rules or grid status, as well as on the possible actions of competitors (69). Hence, the FSPs bidding constitutes an optimisation problem that both large-scale individually committed resources as well as an aggregation service must cope with.

For local congestion management and voltage control the value and efficiency of the service will be contingent on the FSPs proximity in the grid and availability in time. Transparent pricing mechanisms that accurately reflect the value of the service will be important both for FSPs to accurately evaluate their market potential, as well as for SOs to have an efficient market solution for bid selection. If this is not addressed accurately it could result in loss of revenue for FSPs and would lower the financial incentive for more FSPs to provide flexibility to the market.

Energy consumed or generated, in a future moment, can be traded in any energy market that current market design lays ahead of a market participant. A significant factor that impacted perceived risk of whether or not the FSP would be able to recuperate costs on the market was the shifts in flexibility demand as the provision of flexibility would create profits with high variability across time, which increased insecurities regarding return on investment. The experiences from the Swedish demonstrations highlight this issue as many FSPs report that an optimal agreement would be to have clearer communication of how much flexibility is needed and when it will be needed. *Participating FSPs pointed towards a need for shared data platforms, between FSPs and concerned SOs, should be established so that all market participants have equal access to market information (Action-Recommendation 2.4).* As already stated, these platforms need to be well-designed and information easy to interpret and understand. In the Swedish demonstration a function for DSOs to communicate the forecasted need for flexibility in the market platform was tested and implemented to increase transparency. In addition, firm bid agreements or the ability for DSOs to create buy orders that FSPs could fulfil was implemented in the market platform to help mitigate economic uncertainties associated with variations in demand and provide a higher degree of predictability of income.

Insights from the demos: Sweden

For the context of the Swedish CoordiNet demo it is important to understand there is a regional DSO that operates electrical networks (normally between 70 kV-130 kV) in between the TSO's 400 and 220 kV lines and local DSOs. The subscription level is the annual contracted level of power that can be drawn from the TSO grid to the regional grid. In turn, the local DSO will have a contracted subscription level from the regional DSO. This subscription limit is not the physical constraints of the grid which is higher than the subscription limit. Given this particular set up, a context specific solution to increase transparency and communicate flexibility needs was to publish, as a bid in the market platform, the cost of temporary subscription increase (i.e., the cost for the DSOs to exceed the subscription from the transmission grid). In this way, the transparency of the market operation was increased as it was clear whether or not the DSO had been granted this temporary subscription and whether or not they would procure flexibility above or below that cost **(65)**.

However, setting the financial compensation to FSPs in relation to the cost of violating the subscription level was perceived by all interviewed FSPs as resulting in far too low prices for their offered flexibility. Especially for the Uppsala site this was perceived as a problem as the buyer of flexibility has on several occasions been granted a temporary permission to overrun the subscription from the TSO without extra costs. According to some FSPs, this significantly impacted the viability of the market as it kept prices down and, in some cases, meant that there is no need for flexibility purchases **(64)**.

A potential solution to provide stronger incentives for market participation is availability remuneration ensuring a minimum level of reimbursement instead of energy-only markets that only compensate delivered flexibility (MWh). Partly since volumes of flexibility needed is highly dependent on weather, especially in countries with high variation between seasons, this solution provided FSPs a security of remuneration even though a winter season was particularly mild, and thus less energy was used, and less congestion occurred. Likewise, SOs can increase market liquidity and their chances of flexibility being available on the market if need occurs. We will look closer at this potential solution in Theme 3.

4.2.3.3. Providing an accurate baseline

The subject of baseline provision has already been mentioned in passing above and we will now look a little bit closer into this important part of ensuring a well-functioning market. Salient methods for developing a baseline, the basis for comparison that shows whether the FSP indeed modified their consumption or generation, will be important to ensure an accurate settlement process post-delivery. Different baseline methodologies have been proposed and implemented, allowing for the verification of service provision. It is clear that a "one size fits all" methodology is difficult to achieve, as the suitable methodology depends on the intermittency, size, and type of DER. Best practises for choosing the right baseline methodology depending on the DER technology have been developed within the CoordiNet project, which will be furthered discussed in Theme 4 in relation to the settlement process. If the ambition is to attract the greatest possible amount of FSPs in a large-scale flexibility market, all methods will most likely be required to some extent. It will be a challenge to navigate this domain if some general principles are not defined across markets. Here it is also important to note that baselines are easier to determine for bulk generation (or large consumers), as these units are usually individually committed in wholesale energy markets. However, for small DERs represented in an aggregated manner there are no individual consumption and/or production commitments making it more complex for aggregators to provide a baseline. In addition, for these small consumers, stochasticity of consumption and human behaviour plays a big role. Aggregators that make use of LV flexibility can typically overcome this issue by defining aggregated baselines that 'pool' several consumers/flexible devices. At such aggregation level, human behaviour and related stochasticity can be averaged out. However, CoordiNet sees a need to continue to explore this issue to ensure that the provision from aggregated resources can be properly evaluated.

The use of an accurate baseline methodology could also be seen as an important tool to reduce the risk of non-delivery. If the FSP has sufficient knowledge of their normal load curve, and ability to provide an accurate baseline, it will be less likely that an FSP will provide a bid for a product they cannot provide. *When developing flexibility market pilots, the approach, in the initial stages, should be mainly focused on the incentives to participate instead of defining strict penalties for non-delivery of procured flexibility as this might discourage market participation (Action-Recommendation 2.4).*

4.2.4. The independent aggregator

For small market participants, it might often not be economically efficient or too complicated to access markets for system services on their own (70). This creates large opportunities for aggregators that combine multiple customer loads or generated electricity for sale, for purchase, or for auction in any electricity market, as defined in Article 2 n°18 of the Internal Energy Market (IEM) regulation, to provide system services at scale (71). The CEP provides legislative acts regarding market access that are specifically relevant for aggregators as it mandates Member States to enable demand response through independent aggregation. *The aggregator should thus be able to participate in flexibility markets on the same terms as all other FSPs (Recommendation 2.2). However, implementation is lagging, and some Member States have not yet recognised the aggregator role, hampering the participation of this actor. The implementation of the CEP in national law should be facilitated to increase the viability of the aggregator business model, allowing for overall increased liquidity (Action-Recommendation 2.2).*

Broadly speaking the aggregator role is most often taken either by the utility supplying the energy or by other independent third-party market actors. Current market design encourages the former of these two models in which bundling of energy services with the supply contract or with supplier's commercial partners is the easiest option (72). Even though a supplying utility might be in a logical position to take on the role of aggregator, it is also important that other parties can fulfil this role as it brings more competition to the market. This is important given that traditional suppliers take up the role of an aggregator relatively slowly, which could be explained by the fact that demand response services affect their core business, selling volumes of energy (73). In the CoordiNet project and in this roadmap the aggregator framework should be understood to follow these conditions:

- Aggregators are considered as deregulated companies, not linked to regulated agents such as DSOs and TSOs. In this sense, it is possible that the aggregator role is performed either by an energy supplier or by a fully independent agent.
- Aggregators compete in a liberalised market and, therefore, many aggregation companies might be serving different market and system needs at the same time.

- The aggregator, as the agent representing the FSP in the markets, is in charge of managing all the technical considerations and details of the DER technologies and devices being used to provide flexibility in order to maximize the FSP's economic outcomes.

DERs have specific technical characteristics that need to be optimally managed to unlock their flexibility value. To reach their full potential, the aggregator will need to actively communicate with various network entities, the assets represented (and possibly their BRPs) and the DSO or the TSO. The aggregator carries out the estimation of available flexibility, creates bids and market products with that flexibility, as well as operates the end devices to fulfil market agreements. However, for this role to properly be integrated and function well, addressing some key considerations will be important. *To mitigate unique barriers that occur when a third-party acts on behalf of aggregated resources, a harmonised framework establishing the rights and procedures of the independent aggregator is needed (Action-Recommendation 2.2).* As recommended by the ASSET project, the EBGL, SOGL and the CACM should be expanded to ensure a harmonised aggregation framework covering specific aspects such as baseline methodology, measurement, validation and verification (74).

4.2.4.1. Aggregation within CoordiNet

Although they represent a small share of cleared bids, it was demonstrated in the Swedish demonstration that aggregated and smaller FSPs can participate in markets on equal terms (65). The participating aggregators in the demonstration[6] were naturally found to have a more business and financial oriented motivation and drive for market participation as the aggregators main business model centres around these functions. Equally natural, given that this is the core business of these actors they, in general, requested more detailed information such as lists of all grid nodes, a level of information that was not possible to give, as well as impact factors applied in the market, high level of transparency regarding clearing volumes and prices, and indications for DSOs' willingness to pay for flexibility under different circumstances (65).

In the Spanish demonstration two aggregation platforms[7] were developed and tested. The objective of these platforms was to enable aggregation of small-scale DERs in a local and common market for congestion management. All cases in the Spanish aggregation tests were conducted using the Coordinet Common Platform testing environment and, therefore, the redispatches in the baselines of the units, or potential limitations have not been applied in real system operation. However, the developed platforms successfully demonstrated:

- Monitoring of the output of the flexible units in the Malaga demonstration site.
- Estimation of their potential flexibility.
- Providing this flexibility as a bid in the common and local markets, operated by the TSO and the DSO, respectively.
- Receiving of the market clearing results.
- Decision on which units are best placed to be dispatched.
- Controling the response of these flexible units.

[6] The resources the aggregators could control were electric vehicles (either through aggregators' own charger or though car apps/manufacturers' API), heat pumps (through manufacturers' API), or space heaters through local gateways of the aggregator. Also, ventilation systems and industrial processes of large customers could be controlled by one of the aggregators.
[7] Tecnalia AggreFlex platform and Bamboo Energy Aggregation platform.

The bidding strategy implemented in the platform's market optimisation module was constructed to maximise the aggregators' economic benefits in the markets. Inputs include comfort preferences, technical parameters, and constraints of the controlled devices, along with weather and price forecasts (75). This bidding strategy is dependent on the accuracy of the flexibility estimation that can be delivered by the DERs within the portfolio. This is essential to minimise deviations incurred which could result in an overestimation or underestimation of available flexibility. To mitigate this, aggregation models that accurately represent the behaviour of the DERs under different control actions need to be developed. This represents a challenge for the aggregator, since the flexibility that can be mobilised depends on many factors, some of which are subject to a high degree of uncertainty. Many DERs primary function might be to satisfy consumers' requirements that are usually variable and not perfectly predictable, electric vehicles being one such example. This challenge was highlighted in the Swedish demonstration where the flexibility from EVs was mainly available during night-time when plugged in or if there was an occurrence of ample idle time before next use. This means they could provide flexibility for the evening peak from about 17-18 o'clock, in the Uppsala site, but considerably less capacity for the morning peak. Chargers are often connected only after the last trip of the day, or only once or twice a week for larger batteries, unless substantial incentives are implemented for being plugged in at all times.

As previously described, market participants must choose their actions based on their evaluation of likely events and energy consumed or generated, in a future moment, can typically be traded in different energy markets. These features are further complicated when considering ID markets which are continuous by nature, thus giving the aggregator the opportunity to evaluate, make and undo positions multiple times until the gate closure of the ID market, which takes place shortly before delivery. A key component and novelty of the optimisation algorithm[8] in the Spanish aggregation platform is to efficiently manage the payback produced, i.e., the results of previous market sessions and time intervals within the congestion period, to reduce deviations from their trading position. That is, the energy shifted from the congestion time-period when providing upwards flexibility, or from the non-congestion time periods when providing downwards flexibility, is bought or sold in the subsequent ID market sessions.

As described, the bid size required to participate in TSO markets, or in the case of Spain the common congestion market, was too large for the aggregators of small-scale DER. This limit could be considered to reduce market access (more on product formulations in Theme 3). Poorly aligned processes between markets will hinder an efficient process and ultimately reduce access to resources for the SOs. In addition, the technical requirements established in existing markets (e.g., redundant direct connection links with the SO to send real-time measurements with very high time resolution – i.e., 4 seconds) may also pose a strong barrier for both aggregators and individual small-scale DER to participate. As became evident in the demonstration site in Malaga, in some cases the equipment available was too old to support external resource control, whilst in others, the presence of proprietary control software made it difficult to control the equipment.

It is evident that a harmonisation of rules for products and what meter to use needs to take place to unlock the potential of aggregated resources, more on this topic in Theme 3. Both in terms of making sure that technological capabilities are scaled up at a sufficient rate but also to allow access to these resources by aggregators. It is of importance that the aggregator, at minimum, has access to the same amount of grid

[8] A detailed description of this optimisation algorithm is provided in D2.3 "Aggregation of large-scale and small-scale assets connected to the electricity network".

status data, as other individually committed resources to be able to seize opportunities and provide flexibility to the SO (as indicated in recommendation 2.2).

4.2.4.2. The impact of aggregation

In case of an independent aggregator model, the aggregator is not the supplier. The aggregator therefore only offers mediation services and is therefore responsible for the imbalances this service creates. At the same time, at the same access point there is another actor taking up the role of the supplier (who typically also has the role of the BRP or has a contract with a BRP). This leads to complexities because flexibility and energy are highly interrelated. The decision of an independent aggregator to use flexibility on one connection point can therefore impact the energy balance position of the supplier's BRP (76). This can lead to financial risks for both stakeholders. By the creation of the possibility of a third-party aggregation, aggregators are provided the option to outsource this responsibility of portfolio balancing to an already existing BRP (77).

Feedback from larger aggregators participating in the Swedish demonstration, however, show a tendency to prefer being BRP and BSP, themselves. This due to practical issues when individual resources in an aggregated portfolio have different BRPs. Coordinating settlements and trading "back to balance" among multiple BRPs becomes difficult and time-consuming (65). The matter could get complicated further where aggregated consumers have different energy suppliers (each having their own BRP), and the only volume visible is the total aggregated volume and not the volumes of the individual consumer. On the other hand, the aggregator's intervention could in some cases also lead to benefits for the system if the supplier's BRP has an imbalance in the opposite direction of the system imbalance. *These processes resulting from activation of aggregated resources are still new and the effect on the system is still not clear and needs to be further investigated, especially in the case of large-scale aggregation of small DER technologies spread across many customers (Action-Recommendation 2.3). How the potential impact on the system should be corrected is not determined at EU-level and each Member State handles the issue differently. Best practices should be defined regarding how to correct and compensate for possible imbalances caused by the aggregators' market activities (Action-Recommendation 2.3).*

In addition to imbalance issues, actions of the independent aggregator could lead to foregone revenue issues for the energy supplier. It is possible that due to the intervention of the aggregator the supplier has sourced more energy than it can bill the consumer for. This leads to losses for the supplier and a compensation payment is suggested to solve this. How this cost is to be allocated, to the aggregator, or passed on to the consumer via their electricity bill or if this cost is to be socialised is however still an ongoing discussion. Arguments in favour of such compensation state that not having a compensation mechanism leads to market distortions. An argument against a compensation mechanism is that independent aggregation leads to decreases in wholesale prices which are not always translated to retail prices and thus benefit suppliers (73). These and other potential issues that arise from aggregation need to be addressed to not risk resistance for the inclusion of this actor. Article 17 of the IEM does specify that Member States may require independent aggregators to pay financial compensations to suppliers if that compensation does not create a barrier to market entry of these independent aggregators. However, the IEM leaves it up to the Member States to decide upon the details on how to implement different types of compensations (71). Therefore, it is important to treat both the independent aggregator and the supplier on equal footing regarding these imbalance issues.

Correction models to solve some of these issues are called 'transfer of energy', or 'perimeter correction' models (see Table 8). These rules should include an indication on the contractual arrangements and settlement procedure between independent aggregators and the BRP and/or supplier, guaranteeing that the associated BRP and supplier are sufficiently compensated. The determination of proper correction and compensation models is strongly connected to the setting of an accurate baseline (78). As stated above, in general, a basis for comparison exists for bulk generation that are usually individually committed in markets. However, small DERs represented in an aggregated manner does not have this as there are no individual consumption and/or production commitments. Due to this increased complexity several aggregators in the Swedish demonstration noted that providing a good baseline was indeed one of the hardest aspects of participation. More on the topic of baselines in Theme 4.

Table 8. Summary of the most common perimeter correction and transfer of energy models in **(76)**, **(79)**, **(72)** and **(73)**.

Correction models for transfer of energy
In summary, **(76)**, **(79)**, **(72)** and **(73)** discuss five possible types of perimeter correction/transfer of energy models to compensate the BRP and the supplier: 1. The Model without compensation, which is generally applied to enable greater demand response participation in electricity markets. In summary, in this model there is only one BRP, there is no contract between the aggregator and the supplier, and there is no energy of transfer method applied **(79)**. 2. The Regulated model, in which the demand response operators pay the supplier an amount determined by regulation. As such, from the point of view of the BRP, the curtailed energy block is corrected. For the compensation formula, price indices such as the DA price or forward prices are used to cover sourcing costs or foregone revenues of the supplier. In this model, there are two BRPs, but the aggregator does not need a contract with the supplier. The transfer of energy compensation is arranged centrally. 3. The Corrected model, in which the supplier payment is realised through the correction of the customer's metering data/load curves for each activated demand response bid **(79)**. In summary, the aggregator needs to assign its own BRP, but does not need a contract with the supplier. Meter readings are corrected (perimeter correction), and the transfer of energy is taken care of via the prosumer **(79)**. This model needs further regulatory follow-up to ensure that the suppliers do not abuse as they can discriminate flexible consumers through double billing. 4. In the Contractual model the demand response operator and the supplier agree on payments. Currently, in most countries, independent aggregation is mostly possible if an independent aggregator makes contractual agreements with the BRP of the prosumer on that connection point. As noted by **(76)**, this does not favour the level playing field principle as it favours BRPs who take up the role of the aggregator themselves. Furthermore, this model seems to be in conflict with Art 13 (2) of the European Directive 2019/944, which explicitly mentions freedom of the consent of the final customer's electricity undertakings. In summary, in the contractual model, there is a contract between the aggregator and the supplier, and there are two BRPs as the aggregator needs to assign its own BRP and there is a bilateral agreement on the transfer of energy method **(79)**. 5. Finally, **(72)** publishes an entirely new model that allows behind the meter interactions for consumers. They propose a consumer-centric market model in which demand is put at equal footing with generation. The market design is said to require only two changes compared to the traditional market design: decentralised energy exchange on a 15-minute basis between consumers and other stakeholders is allowed (i.e. Exchange of Energy Blocks (EoEB)), and a robust price signal that reflects system conditions in real time is needed. From a technical point of view, the regulated platform or EoEB hub, is a software-based solution that does not require any certified metering. The EoEB hub acts as a single register for commercial energy exchanges. Sourcing energy from different sources without requiring any additional submetering will be facilitated by a supply split **(72)**. The exact implementation of the EoEB hub and needed solutions and processes however still requires further investigation.

4.2.4.3. A note on aggregation of small-scale flexibility providers

Profits from flexibility service provision are most often only significant post aggregation, which might impact small-scale flexibility providers at household level. It goes without saying that prices for demand response must become more attractive for consumers to participate before aggregation of this segment can be a success.

Insights from the demos: Greece

In Greece it was pointed out that including flexibility services as an extra component in the retail contracts offered by the load representatives to the end-consumers could motivate the provision of flexibility. In this way, new revenue streams could be created for the retailers, as they will be able to sell the flexibility services as aggregators via a flexibility platform and ultimately, they could return part of their extra profits via a discount in the end-consumers' charges.

Other research indicates that, without further development of pricing schemes, aggregation focused on residential users will have limited potential (80). In addition, it is suggested that "[…] currently not any single technology meets the consumers' needs for convenience, transparency and usability, and an approach is required that integrates consumer experiences into the product design process to provide solutions that satisfy the consumers" (67). However, other financial incentives to simulate behavioural changes could be accomplished through price signals for end-users, which are not yet properly implemented in most Member States (76), i.e., no time-differentiated network tariffs, no dynamic electricity price contracts and so on.

Experiences from interacting with this segment are however limited and the literature pinpoints that a contributing factor has been that those previous attempts to engage with households have not produced enough feedback. Therefore, there is an insufficient base for drawing conclusions in regard to this consumer segment. Limitations in knowledge is also pin-pointed by Okur et. al. who found in their review that the synergetic relationship between utility customer's financial motivations (i.e., reducing costs and potential for profits) and market financial motivations (the potential business case for FSPs, aggregators, or DSOs) is never fully explored (81). Instead, only one of the two interdependent aspects were investigated in any given study included in their review.

4.2.5. Theme 2 Recommendations

Table 9. Theme 2 recommendations and list of actions derived from the CoordiNet demonstrations and analyses.

Recommendations	Actions	Level of implementation	Priority
2.1 Regulatory barriers should be removed for all types of FSPs to be able to participate in the markets on equal terms.	🏛 The CEP includes that DERs should be able to participate with flexibility, but EU requirements should be revised to make sure to include different types of FSPs as generators, storage, and demand to give all technologies the same possibilities to participate in flexibility markets.	EU	High

	National regulatory frameworks for balancing markets should be revised, as the CEP is implemented, to ensure technology neutrality. All types of DERs (generation, consumers, prosumers, storage) should be able to participate on equal terms in already established markets.	National	High (defined in CEP)
2.3 The independent aggregator should be able to participate in flexibility markets on the same terms as all other FSPs.	The implementation of the independent aggregator in all Member States, in accordance with the CEP, should be stressed.	National	High
	To mitigate unique barriers that occur when a third-party acts on behalf of aggregated resources, a harmonised framework establishing the rights and procedures of the independent aggregator is needed. The framework should as a minimum include common rules for data access, baseline methodologies, the use of metering, and how to validate delivered flexibility.	EU	High
2.4 Processes for activation of aggregated resources are still immature and the effect on the system is still not clear and needs to be further investigated.	Best practice should be defined regarding how to correct and compensate for possible imbalances caused by the aggregators market activities.	EU	Medium
	The effects of the aggregator role, especially how large-scale aggregation of many small DER technologies spread across many customers connected to one aggregator may participate in the market should be specified and evaluated further.	EU & National	Medium
2.5 A viable business case for the FSPs is a key criterion for their participation in flexibility markets.	National regulation should be revised to ensure that proper support and incentivation is provided for FSPs to provide flexibility services. For example, incentives for consumers to provide their electric vehicles as a flexible resource could be one such measure to be explored further.	National	High
	Specific subsidies to small units in the early stages of implementing flexibility markets to cover up-front investments might be necessary to help them reach a viable business case.	National	Medium
	FSPs should be able to participate in several markets, enabling value stacking strategies, to improve their economic efficiency and thereby their return of investment. Likewise, continuous markets could also be an important factor to enable FSPs to increase their financial benefit of participation (see also action 4.1 in theme 4).	National	High
	Shared data platforms, between FSPs and concerned SOs, should be established so that all market participants have equal access to market information.	National	Medium
	When developing flexibility markets, the approach, in the initial stages, should be mainly focused on the incentives to participate instead of defining strict penalties for non-delivery of procured flexibility as this might discourage market participation.	National	Low
	To incentivise small scale actors, with low in-house resources for managing market engagement, an automatic process and	National	Medium

	activation of bids should be in place to save time invested in market participation.		
2.6 Clear and reliable information for FSPs and independent aggregators on how to access markets, as well as transparent processes for FSPs to gain trust.	Rules should ensure transparency in flexibility market operation and bid selection processes to increase the confidence and interest of FSPs, including independent aggregators, in emerging business use cases.	EU	High
	Information about potential business opportunities for FSPs should be made more easily accessible, for instance trough National or regional calls for flexibility services which could be announced on an open portal.	National	Medium
	Develop tools to help FSPs evaluate their potential for flexibility provision and provide guidelines on how they can start engaging in flexibility markets.	National	Low
	User friendly and well-designed platforms and interfaces will be important to bridge information and knowledge gaps that might deter actors from participating.	National	High

* Business
Techno-economic
Institutional and regulatory
"Social"

4.3. Theme 3: Managing SO requirements and FSP capabilities through standardisation

The Challenge: Setting the right level of standards and rules is key to allow for continued innovation and testing of new solutions while at the same time creating a clear and well-defined framework that reduces complexity of participation. In such standards the already discussed requirements and highly regulated environment of DSOs and TSOs must be balanced with the capabilities of new market actors. Striking this balance will be important in order to replicate the CoordiNet demonstrations at multiple sites and support long-term attempts to scale up at EU-level and integrate with other already established markets. To be able to strike this balance a distinction has been made between harmonisation and standardisation, where standardisation is considered more absolute, and attributes are defined using one single value. Harmonisation is considered less confining in the sense that it aims to reduce variations without aiming to achieve one common value per attribute across an entire market.

Key take-aways from the Coordinet experience:

EU-level standardisation of flexibility markets

Firstly, alignment of flexibility products, to avoid further proliferation of product formulations, will be necessary to ensure efficient allocation of flexibility and reduced complexity. However, what is evident in the CoordiNet demonstrations, is that the highly localised application of both congestion management and voltage control will need more trials and research before definitions for product values or ranges will be advisable. For these services, harmonisation of common attributes is advised but strict standardisation of values is not advisable. For balancing products high level of harmonisation across the EU is already achieved with standards set within Member States. To ensure market access for new actors, these standards should be reviewed.

The CoordiNet experience has rather led to the recommendation to carry out regulatory harmonisation to remove barriers that could impact open competition, efficiency, and non-distortion as well as implement general frameworks and principles for these where they are missing. In addition, different terminology is used in Member States within flexibility markets services which easily create misunderstandings and errors. To be able to harmonise processes and further along the market products an agreement on terminology will be needed.

Setting standards and requirements for data flows and platform interoperability

To enable an efficient and well-functioning market, the Coordinet demonstrations all found that standardised processes for collecting measurement data and interoperability is necessary, both between grid components and market platforms. Currently, there is no common European framework to ensure interoperability between flexibility market platforms. If several separate markets exist, different interfaces and market procedures increase complexity, ICT costs, and need for IT-security measures. However, such investments in ICT and IT-security will be unavoidable as development of data exchange systems, as well as the standardisation of systems, protocols, and data formats, is necessary regardless of market design. The costs of implementation will though vary between Member States and could be reduced with standardised processes and ensured interoperability where needed. In the CoordiNet demonstrations, the selection of protocols and technologies for ICT were in many cases forced due to technical reasons or legacy systems. Harmonisation of rules and requirements will be important to promote an environment where choices are guided by best practice and can support an efficient and secure electricity systems. The development and implementation of electricity market data exchange standards would be an advantage that could facilitate the deployment and maintenance of market platforms and communication tools.

When interviewed, FSPs mentioned that standards for market messages, metering data, and baseline provision where areas that would benefit from standardisation to reduce the complexity of market participation. Currently, there is no general agreement at European level on minimum data requirements for flexibility services and what data can be provided on aggregated level or not by FSPs to SOs. Here it becomes important to stress that deployment of smart meters is a prerequisite for proper function of markets. However, as detailed in the draft Framework Guideline on Demand Response put forth by ACER, in countries or regions where smart meter deployment is delayed, rules in Member States must be in place that specify the conditions for the usage of sub-meters.

In accordance with Art. 32 of the Electricity Directive (82), "DSOs […] shall […] establish the specifications for the flexibility services procured and, where appropriate, standardised market products for such services at least at national level" (83). In Art. 40 (6), the same is specified for TSOs, who are now required to establish specifications for non-frequency ancillary services and to develop standardised market products for such services, at least at national level. It should be noted that products for frequency services already have characteristics defined at European level (see art. 25(4) and (5) of the EBGL). In addition, regional initiatives such as PICASSO (for aFRR trading), the MARI (mFRR), TERRE (RR), and the FCR cooperation have provided proposals for product characteristics for balancing services (2). Since standardisation for balancing services is already ongoing at a European level, CoordiNet has focused on the product definitions of the other services within the project. Beyond the specifics of products there are a significant amount of flexibility market rules and frameworks that need to be amended or implemented. It will be crucial to ensure that regulatory and market set ups, implemented for the current market regime, are adapted to accommodate new actors and new functions. Validation of service delivery, grouping of assets, power of attorney ensuring access to data and control of flexible resources by the DSO, protocols for communication, and frameworks for data exchange and security are just some of the aspects that must be considered for standardisation processes. In the following we will explore these aspects further and share insights from the CoordiNet demonstrations to help guide future developments.

4.3.1. Towards a harmonisation of flexibility markets

Already in 2005, Rebours and Kirschen pointed out that it is difficult to compare product definitions due to the plethora of product formulations and context specific characteristics (84). The EU-SysFlex project catalogues in their report a non-exhaustive list of over 100 different products (4). The majority of these products address challenges associated with frequency control, for example balancing products, while there are further product developments expected to address challenges such as voltage control, rotor angle instability, congestion management, and degradation of system adequacy and system restoration capability (4). Alignment of flexibility products, to avoid further proliferation of product formulations, will be necessary to ensure efficient allocation of flexibility and reduced complexity (1). However, what is evident in the CoordiNet demonstrations and will be outlined in this Theme is that the highly localised application of congestion management and voltage control will need more trials and research before definitions for product values or ranges will be advisable. We will explore the reasons for this in the following.

As already mentioned, standardisation can provide significant benefits for flexibility markets. However, the definition of flexibility products is a challenge as product needs and technical requirements may differ between grids and geographical location. To be able to determine an appropriate level of standardisation, an evaluation is needed of the socio-technological context these new products will be part of, i.e., the technological, economic, social, and regulatory factors that shape the electricity markets within Europe and the regional particularities within and between Member States. For example, there will be factors to consider regarding the physical environment, such as grid structure, which imposes specific restrictions and requirements; the stage of economic and industrial development of a region, which justifies the development of different products or imply need for further innovation and therefore flexibility in product requirements; and cultural factors such as experience of DSOs in active grid management (85). However, there is agreement among key stakeholders, in the energy sector with a connection to smart grids and flexibility markets, for a set of general product principles including:

1. "flexibility products must comply with the [SOs] needs" (86). Such requirements should be specified at national level and a sufficient degree of transparency is needed to ensure mutual understanding of requirements and capabilities, while taking into account technology neutrality.
2. As such, when decisions on harmonised attributes are made, this should be done together with concerned (national) stakeholders (1). More specifically, the final choice on product design should be left to the Member States and their NRAs so that specific local circumstances can be accounted for (86).

3. It is important that there is alignment between different products (for balancing, portfolio optimisation, congestion management) (1). However, this does not imply that harmonisation between all products is recommended or even possible at early stages of market development. ENTSO-E and the European Associations representing DSOs highlight that "compared to the products currently used by the TSO, the DSO will need flexibility products that are more granular and that can be used over a wider time span" (86).
4. Flexibility product design should allow for easy participation of aggregated resources, including aggregation of smaller number of customers and assets. This implies small bid sizes, that activation should be allowed to be aggregated, and that reaction time and notification period should be sufficient so that aggregators have enough time to respond (53,54).
5. In both Spain and Sweden, where the flexibility demand is strongly dependent on the ambient temperature, an important factor for continued development is to include a temperature dependence in bids as this will aid in properly evaluating the available flexibility (65,87).

To achieve these principles, regulatory sandboxes can provide a relevant tool for product feature discovery, so that regulators can define which are the most appropriate products for the Member State in question. Creating too detailed and strict standards for new flexibility products could come with clear disadvantages since it risks reducing market agility to deal with characteristics that can be highly context dependent (85). The maturity of flexibility markets is across the board quite low and variations between Member States will be significant in terms of technological capabilities and cultural readiness (within organisations). At such an early stage of market development there are other aspects of flexibility markets in need of harmonisation, other than defining specific product attribute values, such as frameworks ensuring open competition and non-distortion. Concerning the definition of products ENTSO-E, CEDEC, E.DSO, Eurelectric, and GEODE recommends to firstly develop a common non-exhaustive list of attributes for new flexibility services (25). This recommendation has been applied in the CoordiNet project and the products defined have utilised the common terminology for product attributes that are illustrated in Figure 13. The product attributes are either defined in the NCs, taken from literature or real examples, and/or a result of discussions among the project partners. For each grid service, one or more standard products have been defined with ranges of values and are described in detail in deliverable D1.3. For a description of these attributes please see Appendix D.

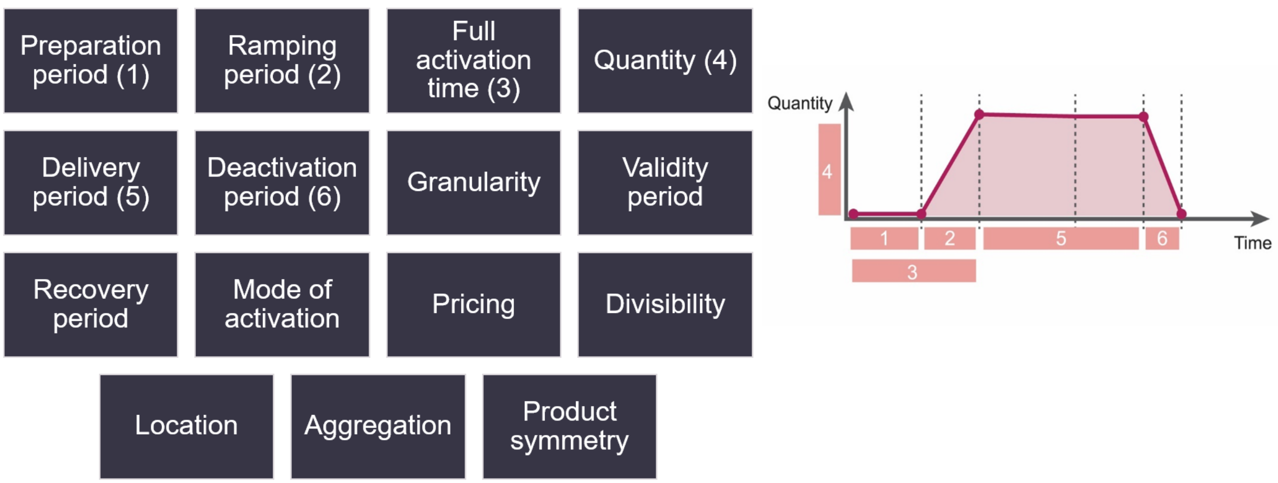


Figure 13. The common list of attributes is suggested to contain the parameters included in the illustration. The numbers connected to the attributes responds to the schematic of a product description (right). Illustration sourced from CoordiNet deliverable D1.3, adapted from (14).

When defining these characteristics some general assumptions where made. All assumptions took technology-neutrality as a given pre-condition. These assumptions where:

- Aggregation is allowed wherever possible, so that a portfolio of DER is able to deliver the different services.
- The minimum quantity or bid size was set at 100 kW or 1 MW, in case of active power, for most services to lower the threshold for DERs to participate in the market.
- Asymmetric products were allowed wherever possible so that all types of flexibility, including all types of DER, could participate on equal terms.
- Along the same lines, divisible bids were allowed when possible.

Secondly, it is of high importance to develop principles for the product prequalification (25). The CoordiNet demonstrations have, throughout the project, found that processes for prequalification would greatly benefit from standardisation to reduce market complexity and lower market entry barriers. In the following we will discuss both these two aspects further in relation to the demonstration results.

The mentioned need to focus on additional aspects than detailed product values is also captured in Art. 32 of the Electricity Directive which states:

> "The specifications [for the flexibility services procured] shall ensure the **effective and non-discriminatory participation** of all market participants, including market participants offering **energy from renewable sources**, market participants engaged in **demand response**, operators of **energy storage** facilities and market participants engaged in **aggregation**."

From the experiences gained within the CoordiNet project it is possible to say that the above-mentioned ambition is still in need of regulatory review and facilitation and should be the primary focus. *Even though EU-wide product harmonisation is needed for flexibility services, regulatory harmonisation of other processes and requirements should be prioritised before this is possible (Recommendation 3.1). General principles should be defined regarding competition, efficiency, and non-distortion, which are missing at the moment. Detailed regulatory frameworks based on these general principles should be defined by the Member State/NRAs (Action-Recommendation 3.1).* The CoordiNet partners assert that emphasis should be on enabling and fostering fair competition, removing barriers for new participants to contribute to and benefit from market participation. *For example, different terminology is currently used in Member States for flexibility products and services which easily create misunderstandings and errors. A common terminology should be developed and implemented on EU level, so all Member States use the same definitions and terms (Action-Recommendation 3.1).*

One such factor that could negatively impact market access, and should be prioritised for revision, was mentioned in Theme 2 and regards cases where regulations and/or product standards create unfavourable conditions for specific technologies. *Currently, EU technical requirements for generators, storage, and demand are not technology neutral, which is evident in the case of energy storage. Different restrictions for different types of loads could favour market penetration of specific technologies/actors and it is recommended to revise regulations to ensure fair competition (Action-Recommendation 2.1).* The 2020 SmartEn monitoring report gives an overview of the implementation in different Member States of the EMD with regard to demand-side flexibility (88). It concludes that, in general, there is weak progress on the implementation of demand-side flexibility provisions. At the time of writing, most of the EU directives put forth in the CEP had not been fully implemented and in the following chapters, results from the scalability and replicability analysis (SRA) of the CoordiNet demonstrations, along with five additional countries[9], will help outline the status regarding the ability of DERs to provide system services. The results from this SRA were attained via a questionnaire sent out to the TSO and DSOs of the included Member States in the analysis. For the full analysis please see CoordiNet deliverable D6.4 (37).

Insights from the demos: Spain

As new actors and technologies are to participate regulations must be reviewed to ensure that these new players can participate on equal footing. An example can be given from Spain where, contrary to balancing market regulation, demand flexibility for congestion management was not supported by current national regulation.

4.3.1.1. Added value of coordinated markets and services

A common market, where both TSOs and DSOs act as buyers, has higher requirements in terms of activation time, minimum bid size, communications, etc. which can be a barrier for some small resources, particularly those connected to the lower voltage levels and the product needs to adapt to the availability of flexibility. *It is also important to ensure alignment between different market requirements, in the case of separate markets for DSOs and TSOs. This will increase efficiency of market participation as one product could fulfil several services in different markets and will thus aid in increasing overall liquidity and market efficiency (Action-Recommendation 3.3).*

To support increased coordination the CoordiNet demonstration also states the need for specifying conditions for how capacity products and energy products could be linked and traded on a joint market platform (33,40,47). When trading capacity products, rules for when in time activation is permitted and the amount of delivered energy need to be determined. The product definition should specify these conditions. As mentioned in Theme 1, long term reservation of flexibility might be a precondition for DSOs for the deferral of grid extensions. This is necessary because grid extensions are planned well in advance and might need several years[10] to be commissioned (40). Therefore, harmonisation of capacity products, especially on distribution level is needed as the DSO is still lacking experience in handling these types of products in comparison with the TSOs. At minimum, the product definition should specify conditions for activation periods to clarify the amount of expected delivered energy.

[9] In the D6.4 analysis an in-depth study was carried out on the regulatory frameworks in the demonstration countries, Greece, Spain, and Sweden, and five additional countries: Austria, Belgium, Germany, Italy, and the Netherlands.
[10] This period of time might be longer due to specific administrative permits.

4.3.1.2. Balancing

Table 10. Balancing products included in the CoordiNet demonstrations.

BUC	FCR	aFRR	mFRR	RR
Spain: ES-2 (Balancing services for TSO)			X	X
Sweden: SE-2 (Balancing services for DSO)			X	
Sweden: SE-3 (Balancing services for TSO)			X	

On one hand, balancing services are procured in what can be considered liquid and well-implemented markets in most countries. Products for this type of services are standardised across Europe by the EBGL (18), and are now starting to be traded cross-border with the implementation of the European platforms for the exchange of balancing energy (89). ACER already published in 2020 a methodology for a list of standard products for balancing capacity for frequency restoration reserves and replacement reserves (90,91). The different products, see Table 10, have varying characteristics in terms of activation time and automatization, which could limit the potential for DER participation. In addition to product harmonisation, the EBGL also provides additional instructions on market design aspects that are relevant. More precisely, the EBGL provides important guidelines for the participation of DER[11] connected to the distribution grid in balancing markets. The EBGL calls for a level-playing field for all market participants, including demand-response aggregators and assets connected to the distribution grid in the provision of balancing services. In the SRA, potential for replication of the BUCs regarding DERs ability to participate in balancing markets was analysed and was translated into a rating, from 0-5, attributed to each country with a more detailed summary for the demonstration countries (see Table 11) (37).

Table 11. Assessment for DER potential to participate in balancing markets in the demonstration countries and five additional Member States that were selected for detailed SRA. In general terms, a rating of 5 means that the status in the specific country is completely compatible to what is needed for the replication of the CoordiNet's BUCs. What can be seen is that several countries already have balancing markets open to DER and practical limitations for their participation is limited. Adapted from CoordiNet deliverable 6.4.

Q1	Can DER participate in balancing markets?			
Q2	Are there practical limitations to DER participation (e.g., min. biz size, symmetrical bidding)?			
Q3	Are all types of DERs allowed to participate in balancing markets?			
	Q1	*Q2*	*Q3*	*Short rationale*
Greece	1	0	0	As of writing, there is no regulatory framework which allows the participation of DER in ancillary services markets. Only conventional units can provide ancillary services and participate in ancillary service markets. Nevertheless, according to ENTSO-E guidelines and the Greek energy market Target Model, ancillary service markets are foreseen to be open to DER in the near future and the suggested minimum bid size for aFRR and mFRR is 1MW (92).
Spain	4	3	5	DER can participate in balancing markets (aFRR, mFRR and RR). DR, DG, ESS and aggregators can participate. Minimum bid size (1MW) and technical requirements (the same regardless the size of the unit) may limit participation.

[11] The EB Guideline mentions demand facilities, energy storage facilities, generation facilities, and the aggregation of these units.

				Until recently, Spain could be considered a country closed for DER participation in balancing markets. However, in December of 2019, a new resolution was approved by the regulatory authority in the national terms and reference from the EBGL. The resolution recognises four types of balancing providers, generation, demand, storage, and aggregators (37). Minimum bid size is set to 1 MW and DER units can participate in aFRR, mFRR and RR provision. Units have to be able to comply with the required information exchange (both structural data as well as real-time data) through a dispatch control centre.
Sweden	5	3	5	DER can participate in balancing markets. However, requirements (e.g., bid size) may limit participation. One product however is set to have a minimum provision from DER. The Swedish regulatory framework is extensively linked with Norway's, Finland's, and Denmark's regulations. The Nordic countries share a single market and regulation (despite having different TSOs). In principle, demand response is allowed to participate in demand response in the Nordic ancillary service markets. Sweden does allow the participation of DR and aggregation, for FCR and mFRR products. However, a minimum bid size of 5 MW in SE4 and 10 MW in the rest of the country may be a barrier to DER participation (93). There is a Strategic Reserve service in Sweden, similar to the mFRR, in which 25% are to be provided by DER (93).
Austria	5	3	5	Balancing markets are open to DER and incentives exist for their participation. Prequalification processes can be complex and communication requirements can be a barrier.
Belgium	5	5	4	DER can participate in FCR and mFRR, Interruptible Service (demand response exclusive) and Strategic Reserve.
Germany	5	4	5	DER can provide most balancing services and minimum bid sizes is 1 MW for most cases
Italy	2	2	2	DER can participate in experimental projects for balancing provision. Only aggregated units can participate. High metering and testing requirements still present a barrier to DER participation.
The Netherlands	4	3	4	Balancing markets are open to DER participation, but practical limitations exist, such as symmetrical bids and high minimum bid sizes.

Evident in the table is that, as of today, balancing markets across Europe are not fully harmonised, and therefore, specificities in every country matter in terms of replicability of the CoordiNet BUC's and the potential for DER to participate on these markets. Nevertheless, a harmonisation effort is taking place as a consequence of the implementation of the NC and GL (15). The EBGL calls for standardisation of balancing products to a certain extent. Within the scope of the EBGL are the pan-European balancing platforms that will trade the balancing products across borders, namely the aforementioned platforms PICASSO (for aFRR trading), MARI (mFRR), and TERRE (RR) (15). It is important to note though, that the standardisation proposed by the EBGL does not aim to be complete, but rather sufficient to allow cross-country trading between the different balancing markets. However, simply enabling DER and demand response to participate and harmonising product design is not enough unless additional requirements and market conditions change as well.

In Spain, the main challenge found in the demonstration was not the specifications of the product traded but the new functionalities that would be required by the TSO platform, eSIOS, which would necessitate an update to the market optimisation algorithm. Since this is the most critical platform for managing these services in Spain this will impose risks of knock-on-effects as changes in the algorithm, to allow for new service providers and technologies to supply balancing products, could result in the malfunction of other processes carried out by the platform.

In the Swedish demonstration a storage unit successfully demonstrated the capacity for simultaneous participation on both the local market and for the mFRR, manual frequency restoration reserves, balancing market. However, many FSPs in the Swedish demonstration found the stricter prequalification criteria for the mFRR to be a deterrent for providing flexibility both to the local DSO and TSO balancing markets. The higher criteria are designed on a European level to realise cross zonal trade between TSOs in Europe. This experience highlights the fact that standards for prequalification process are important. It was stressed that the criteria must allow also smaller actors to participate. Deeper dialogue with the Swedish FSPs revealed that owners of many of the new types of resources like batteries and electric vehicle (EV) chargers, as well as mature aggregators, preferred the frequency containment reserve market, FCR-D[12]. The FCR is the fastest type of reserve, and therefore critical for the system. For this reason, several countries such as Spain do not trade this service in an organised market, but rather consider it as a mandatory service for generation units able to provide it. Additional, trials should be done to explore this option further. The reasons for their preference for FCR-D were several:

- FSPs can participate on the FCR market with only 0,1 MW (instead of 1 MW for mFRR)
- FSPs can participate on the FCR market for only 20 min duration (instead of 1 hour for mFRR)
- The capacity nature of the market where capacity can be sold all hours of the year with higher compensation.
- Limited and short activation during the rare periods the frequency is outside of its normal operating window. In Sweden this typically only occurs for a few seconds and normally only a few times per month. Only in extreme grid collapse events a full activation period of 20 minutes would be required.

Some FSP also expressed a desire to integrate with the automatic restoration reserve market, aFRR, as the product prequalification process was perceived as less complex. The aFRR is the second reserve to be activated in case of a grid event. It is a fast reserve, and therefore units have to comply with more complex requirements to be prequalified for the provision of this service.

Insights from the demos: Sweden

In Sweden the regulations pertaining to FCR were developed for specific use of hydropower. However, the recent developments regarding the rules for FCR have increased interest in the potential business case of provision. The reason for this is that FCR has a capacity renumeration while mFRR only has an energy-based renumeration and this remuneration model was favoured by many of the participating FSPs in Sweden to reduce their risk of market participation, as explored in Theme 2.

4.3.1.3. Congestion management

Table 12. Congestion management products included in the CoordiNet demonstrations.

BUC	Capacity	Energy
Spain: ES-1a (common)		X
Spain: ES-1b (local)		X
Sweden: SE-1a (multi-level)	X	X
Greece: GR-2a (multi-level)	X	X
Greece: GR-2b (fragmented)	X	X

The congestion management products tested in the Coordinet demonstration can be seen in **¡Error! No se encuentra el origen de la referencia.**. It has been verified that congestion management is a very unharmonised service among the countries that underwent the detailed SRA, see Table 13 (37). In addition, EU regulation does not provide a common definition for a market-oriented service provision and does not set specific rules for congestion management markets for solving internal congestions (37). Balancing and congestion management are two services that are tightly coupled on HV levels. Hence, the potential for

[12] **F**requency **C**ontainment **R**eserve **D**isturbance

service coordination in HV levels is higher. The lack of clarity on EU-level on congestion management procedures is an important barrier for the replicability of the CoordiNet BUCs that consider the use of DER by TSOs in specific congestions management markets. **¡Error! No se encuentra el origen de la referencia.** displays the rating attributed to each country for the question on the potential for DER provision of congestion management services on HV levels to TSOs.

Table 13. Assessment table for the potential of DER participation in congestion management for TSOs in the demonstration countries and five additional Member States that were selected for detailed SRA. In general terms, a rating of 5 means that the status in the specific country is completely compatible to what is needed for the replication of the CoordiNet's BUCs. Sourced from CoordiNet deliverable 6.4 **(37)**.

Q4	Can DER participate in congestion management markets?	
	Q4	*Short rationale*
Greece	0	DER cannot provide congestion management services
Spain	2	Only DER scheduled in the DA market (in principle connected to the HV grid)
Sweden	2	DER can be used, but currently only mFRR bids are used
Austria	1	Only for emergency purposes
Belgium	0	DER cannot provide congestion management services
Germany	3	DER can provide congestion management depending on local requirements
Italy	2	DER can provide congestion management under pilot projects
The Netherlands	4	DER can provide congestion management services to the TSO through the GOPACS platform.

The main focus for congestion management within the CoordiNet demonstrations is however the provision on lower voltage levels to the DSO. The SRA provides insight on some key factors necessary for congestion management services to be successfully implemented on a local (or other market models discussed in this deliverable) flexibility market for procurement by DSOs, in line with the definition brought forward by the CEP. The CEP states that "the DSO should establish the specifications for the flexibility services procured", but as stated, provides no further details as to how it is to be implemented (14). Since procurement of capacity products by DSOs is mostly only done in the context of research projects such as CoordiNet or some small-scale pilot projects, a harmonised market and regulatory framework for products has not been established yet (94). Member States may adopt specific congestion management markets, such as the CoordiNet flexibility markets, or not. Besides relying on non-costly mechanisms to solve congestions (e.g., changes in topology), countries can use countertrading or even balancing markets to solve congestions without using redispatch-specific markets. Two key factors are represented in Table 14 below, with a more detailed description for the three demonstration countries, regarding the possibility of utilising congestion management products provided by DERs for flexible system services at DSO level. For the full analysis of all countries, please see deliverable D6.4 (37).

Table 14. Assessment table for potential of DER provision of congestion management in the demonstration countries and five additional Member States that were selected for detailed SRA. In general terms, a rating of 5 means that the status in the specific country is completely compatible to what is needed for the replication of the CoordiNet's BUCs. Source from CoordiNet deliverable 6.4.

Q10	Can DER provide services to the DSO in any form (e.g., non-firm connection agreement)?		
Q11	**Is there regulation for market-based procurement of flexibility**		
	Q10	*Q11*	*Short rationale*
Greece	3	3	A regulatory basis for the activation of distributed Demand Response by the DSO has already been established under Article 28 of the Hellenic Electricity Distribution Network Code, however there is no implementation yet of DER flexibility for local grid management purposes. The European

Q10	Can DER provide services to the DSO in any form (e.g., non-firm connection agreement)?		
Q11	**Is there regulation for market-based procurement of flexibility**		
	Q10	*Q11*	*Short rationale*
			network codes are still under discussion and the subsequent national implementation is also pending.
Spain	2	2	DSOs can use DER to solve congestions (only with generation units) in the common market platform and in the same way as the TSO does. However, once those congestions are identified as well as the generation units that have an impact on the congestion, these needs are sent to the TSO who accesses the bids and calculates the necessary redispatch to ensure solving the detected constraints (95). Still, this scheme is only for short term flexibility (day-ahead and real time), and only for generation DERs whose minimum capacity is higher than a threshold. Demand-side flexibility cannot participate. As of today, no comprehensive new regulation on the use of flexibility by the DSO has been published. However, a few initiatives have been initiated towards this goal such as pilots and a sandbox regulation which has been published.
Sweden	4	1	The DSOs can have bilateral agreements with DER for load reduction and increase of DG production (15). Nevertheless, there is no specific regulation defining the characteristics of these bilateral agreements, being the DSOs the responsible for setting the terms of these agreements.
Austria	1	1	No regulation specifically on local flexibility.
Belgium	2	1	Local flexibility can be used, although not remunerated.
Germany	3	1	No regulation specifically on local flexibility. Large scale projects are testing local flexibility provision to DSOs.
Italy	2	1	No regulation specifically on local flexibility. A sandbox regulation was recently published.
The Netherlands	3	1	No regulation specifically on local flexibility. Large scale projects are testing local flexibility provision to DSOs.

At EU-level, in comparison to balancing products, much less progress has been achieved for congestion management at the distribution level. As can be seen in Table 14 above, the SRA in D6.4 verified that congestion management is to an extensive degree heterogenous in nature among the studied countries and significant barriers exist for DERs to provide congestion management services. The examples provided from the D6.4 analysis also provide evidence to the CoordiNet recommendation to address other aspects of flexibility market harmonisation, other than defining specific product attribute values. The case of congestion management illustrates this well and previous projects have instead chosen to distinguish between standardised and harmonised products, in which standardisation is considered more absolute and relevant attributes are defined using one single value (85). Harmonisation is considered less confining in the sense that it aims to reduce variations without aiming to achieve one common value per attribute across an entire market. The CoordiNet project findings support the same approach. *For congestion management, harmonisation, aiming to reduce variations, rather than standardisation, defining single product values, is recommended. Flexibility markets are too immature and in need of continued innovation. (Recommendation 3.2). For congestion management some general principles should be developed, such as a common list of attributes from which all Member States can choose the ones needed for national specific products (Action-Recommendation 3.2).* However, some key elements and attributes that the demonstrations have highlighted as of greatest importance to harmonise were communication protocols and bid size (33,40,47). Here lies the challenge of striking a balance between establishing frameworks and harmonising processes and products in a way that will create stability and trust in the market functions without stifling the necessary continued innovation and development.

Implementing flexibility markets for congestion management have proven a feasible and efficient solution in the CoordiNet project. In the CoordiNet flex market, remuneration of congestion management service provision was initially only done by pay-as-clear remuneration, i.e., for energy-only products, the most widely adopted method (e.g., in CoordiNet, INTERRFACE, and EU-SysFlex). What has become evident however in the Swedish demonstration, is that market liquidity was impacted by the remuneration method[13]. Based on FSP feed-back, an energy only market for congestion management is unlikely to have enough liquidity. An energy-only market compensates delivered flexibility (MWh), while availability remuneration compensates the mere readiness to provide flexibility. As became evident in the demonstrations, the volume of flexibility need can vary significantly between seasons and years, as exemplified in the Swedish demonstration where a mild winter significantly reduced the need for flexibility. At such instances, the incentives for FSPs to participate were too low and risk of not recuperating costs for setting up supply processes became too high. The analysis provided by the Swedish demonstration therefore points to that DSOs must ensure a minimum level of reimbursement and set up the market for both energy-only and availability remuneration. Since some FSPs would not participate with availability remuneration both are needed. Thus, CoordiNet findings supports the analysis in (96), stating that flexibility products should be remunerated considering not only product delivery but also availability. For this method to be successful however, the increased costs for DSOs to remunerate by product availability must be taken into consideration as it would increase risk of making grid reinforcement the least costly solution and could deter from setting up a flexibility market (96).

4.3.1.4. Voltage control

Table 15. Voltage control products tested in the CoordiNet demonstrations.

BUC	Voltage control Active power	Voltage control Reactive power
Spain: ES-3 (Common)		X
Greece: GR-1a (Multi-level)	X	X
Greece: GR-1b (Fragmented)	X	X

Voltage control is in a similar situation as congestion management, in which countries have different mechanisms to solve this problem, often following a rule-based approach and could be both remunerated and not remunerated, which is a clear barrier for the replicability of the voltage control BUCs. For voltage control, active and reactive power can be used, as indicated in Table 15. Here, in this section we will briefly focus on some general aspects to consider for voltage control with emphasis on active power products. In CoordiNet more emphasis was placed on trials for the novel approach of market-based procurement of reactive power. Hence, more details from the demonstrations are presented in Theme 5. However, it is important to keep in mind that on the distribution level, there is a bigger interdependency between reactive and active power on the demand side as a combination of active power and reactive power can solve the DSO needs and active power and reactive power delivery is often linked from the flexibility provider's perspective.

For voltage control, there is a set of rules and mandatory technical capabilities established at European level, mainly related to technical requirements for generators, established in the RfG NC, Regulation 2016/631 (97), and for demand in the DCC NC, Regulation 2016/1388 (98), and their corresponding national

[13] To consider in this particular case in Sweden is that the incentives for the DSO to utilise available flexibility was lowered by the relative ease in which they were able to temporarily increase their subscription level. Meaning, that this particular result will only be applicable in similar contexts where the cost of an alternative solution is lower than procuring flexibility from FSPs.

implementations. These should, as for all other products, be reviewed to ensure market access and technology neutrality. There are however some discrepancies in this perception of high-level frameworks for the setup of markets and product definitions regarding voltage control. Perhaps due to longstanding experience with management of this service, TSOs deem the advancement of EU-level frameworks and principles a low priority while DSOs, with no to little previous experience with this service, deem it to have high priority (56). The main reason for this difference in prioritisation is probably that, in general, there is only one TSO per Member State, whereas there are several DSOs. Both TSOs and DSOs, however, do agree that suitable voltage control attributes may still be listed at EU-level, non-exhaustively, for DSOs to use. The high-level principles point out, among others, that specification of product parameters shall match the characteristics of the SO's network to whom the resource is connected, and that these characteristics may be tailored to address specific topological or locational issues. The TSO or DSO to whom the resource is connected shall have the right to specify voltage control products, for use on their network only, and shall have the sole right to send voltage set-points directly to the resources connected to its grid based on the applicable national data exchange scheme. The existence of different perspectives is not seen as a barrier in itself for implementation, as products and procurement mechanisms can be tailored at local level to enhance the framework's effectiveness from the DSO perspective. With this in mind it is sensible to not make EU wide standardisation a priority but focusing on putting in place a common list of attributes and upholding the need for harmonisation between DSOs and TSOs within each Member State. Given that the TSO and DSO networks are coupled, a coordinated TSO-DSO approach to voltage control, on common attributes and market functions, can bring savings through optimal operation at the system level, to avoid counteracting activations, minimise losses in the whole grid and enhance voltage stability (56).

According to the SRA, DER could technically be involved in decentralised active power provision to solve local grid problems in the EU today. The analysis in (77) highlights that the DSOs can resort to FSPs for voltage control. However, in the EU third-parties' participation in voltage support is still in its early stage and there are none or limited market-based mechanisms in force to procure voltage support (99). According to the SRA, DER could technically be involved in decentralised active power provision to solve local grid problems in the EU today. The analysis in (77) highlights that the DSOs can resort to FSPs for voltage control. However, n the EU, third-parties' participation in voltage support is still in its early stage and there are none or limited market-based mechanisms in force to procure voltage support (99).

4.3.1.5. Controlled islanding

Table 16. Demonstration site for controlled islanding in the CoordiNet demonstrations.

BUC	Controlled Islanding
Spain: ES-4	Frequency & voltage control

The objective of the Spanish BUC was to assess the ability of the DSO to operate part of the distribution network in an islanding mode during outages or planned maintenance services and without using balancing services (87). In this use case, the aim was to isolate a section of the distribution network by maintaining supply with local generation and storage resources. Within the scope of the project, controlled islanding was defined as a DSO-exclusive service. Other controlled islanding services could be envisioned for the TSO. However, this would lead to a different BUC than the one proposed in CoordiNet.

This use case was conceived as a service agreed with the FSPs. No automated processes were triggered in this case since the interaction of the FSP with the DSO was already fully automated. In the case of planned maintenance, information on the need is provided to FSPs beforehand. In the case of unplanned outages, an operation is communicated directly to the FSP. The main objective of this BUC was to test the whole process of prequalification of potential providers and activation of the corresponding resources for the controlled islanding service which resulted in:

- The definition of specific attributes that apply to each of the cases of planned and unplanned outages to be able to simplify the requirements and reduce the entry barriers for a service that is very specific by nature.
- The specification of the information and commands to exchange between the local platform and the FSP to create the island keeping the quality of service, at least when no sudden events occur while the system is in the island mode.
- The implementation of the whole process on a local platform. It must be taken into account that the FSPs operation mode was known to the SO operating the platform which might not be the case for other FSPs that might participate if market-based procurement would be implemented. Therefore, the control of the island operation should be kept in the hands of the corresponding grid operator, even if the energy could be provided by the FSP, given it is a service that may be used limited times per year.

The tests for this BUC could successfully demonstrate the controlled islanding service is technically possible. Moreover, it also identified important aspects of the islanding operation. For example, the presence of a storage system was critical, as it provided "local balancing" during the islanding state. Given the novelty of this BUC, the tests were focused more on the technical aspects of the BUC rather than on its market setting. Therefore, market-related questions such as the liquidity of an islanding product or the need for long-term procurement by the DSO to ensure the service provider when needed, especially in the unplanned outage case, are to be further investigated (100). However, it can be stated that the service itself is so specific in terms of its location of implementation, and in terms of the necessary attributes to provide it by a third-party FSP, that it is unlikely to have a competitive market for this service in the future. This peculiarity makes this service more likely to be delivered through bilateral contracts rather than local organised markets (87). Nevertheless, most countries have continuity of supply incentives, which would already provide an incentive to the controlled islanding service (37).

4.3.2. Data exchange and information flows are key for market implementation

The recast of the Electricity Directive (EU) 2019/944 in the CEP enables the EC in Article 24(2) to adopt implementing acts specifying interoperability requirements and non-discriminatory and transparent procedures for access to data. Article 23(1), of the same directive, states that "data" is understood to include metering and consumption data as well as data required for customer switching, demand response and other services. Ultimately, this shall serve to facilitate the full interoperability of energy services within the Union as defined in Article 24(1). When interviewed, Swedish FSPs mentioned that areas that would benefit from standardisation to reduce the complexity of market participation, were standards for market messages, metering data, and baseline provision, which all concern the aspect of information collection and data sharing. Here it becomes important to again stress that for service provision to be possible, and the standards requested by the CoordiNet FSPs to be applicable, deployment of smart meters is a prerequisite. However, as detailed in the draft Framework Guideline on Demand Response put forth by ACER, in countries or regions where the deployment is delayed, rules in Member States must be in place that specify the conditions for the usage of sub-meters (12).

In addition to the need of securing metering data from potential flexibility resources, as detailed in Theme 1, sharing of network information between SOs for secure and accurate market clearing is a major dimension of the coordination schemes defined in CoordiNet. The development of data exchange systems, as well as the standardisation of systems, protocols and data formats, is necessary regardless of market design (101). Information and data flows will also be key in proper management of an increasing complexity in the different phases of the market (the details of these market phases will be further explored in Theme 4). Information sharing requires digitalisation of networks and upgrading of IT infrastructures and cybersecurity practices which increase costs for market implementation. The development and implementation of electricity market data exchange standards would be an advantage that could facilitate the deployment and maintenance of market platforms and communication tools (33,40,47). ICT costs will also impact market participants who need to invest in ICT that meet the system specifications and requirements. With the increase of data flows between all actors within a flexibility market, the added dimension of streamlining requirements and processes across different markets and ensuring interoperability between platforms and components will be key to reduce the overall system complexity and make it easier for new market entrants to increase their level of participation. *However, there is no general agreement at European level on data requirements for flexibility services and which data that can be provided on aggregated level or not by FSPs to SOs. Some minimum requirements on data should be established and could advantageously be implemented in the process of product harmonisation, including aspects such as granularity, accuracy, level of data aggregation acceptable etc (Action-Recommendation 3.4).* This recommendation is also directly linked to the need for specifying the conditions for usage of sub-meters (12).

In the following we will briefly touch upon these two aspects of harmonisation of information sharing, firstly aspects of harmonising the requirements for information and data flows between market participants, and secondly the important factor of information sharing between SOs and the interoperability between markets.

4.3.2.1. Harmonisation of data and information requirements

In the CoordiNet demonstrations, the selection of protocols and technologies for ICT were in many cases due to technical reasons, in other cases, the decision was forced due to legacy systems. *Impact of legacy systems should be evaluated and considered, as the cost of integration have a strong impact on the overall economic efficiency (Action-Recommendation 3.5). Harmonisation of rules and requirements, regarding gathering measurement data, will be important to promote an environment where these choices are guided by best practice and can support an efficient and secure electricity systems (Recommendation 3.4).* Clear requirements for digitalisation and metering could also increase the overall incentives for scaling-up the roll-out of solutions that would facilitate both FSP participation and increase the visibility in LV grids for DSOs. However, in the medium term it must be taken into account that the technical and personnel effort required is considerable, which must be considered when planning for large-scale application (102). In Greece, some FSPs deemed it necessary to increase the rate of digitalisation of processes and metering roll-out to guarantee their participation in a flexibility market. *Efforts should be made to promote an accelerated deployment of monitoring and measurement tools to improve digitalisation and grid observability. The EU DSO Entity and ACER should perform an active role in monitoring the national implementation of the flexibility markets and highlight best practices in each Member State.* Without harmonisation of rules for real-time telemetry, improvement of visibility in LV-grids to ascertain locational characteristics of FSPs will be difficult to achieve. This hinders the ability for SOs to assess and address flexibility needs, and FSPs to participate on the market. *To make smart meters data accessible and possible to use, standards for processes and power of attorney must be developed between the SOs and the FSP (Action-Recommendation 3.4).*

Insights from the demos: Spain

In the case of the Spanish local congestion management demonstration, the biggest challenge was especially the installation of monitoring and control devices for the flexible resources and the LV network. The process of installing the necessary components was lengthy and was customised for every flexible resource. Monitoring and measurements need to be improved and roll-out facilitated since potential FSP resources are not prepared or equipped to participate in a flexibility market. A recommendation that was given from Spanish FSPs was to establish economic incentives with regulatory support to install elements that monitor and control the installation remotely, to facilitate the large-scale flexibility market and aggregation. Establishing these markets with stronger institutional support sends a strong economic signal related to the provision of flexibility in markets.

4.3.2.2. Interoperability for reduced complexity and increased efficiency

It is easy to understand why interoperability is the buzzword of the last years, considering its capacity to unlock great potential for flexibility services. However, it is generally considered one of the most challenging aspects. According to (103) one of the main problems for data sharing is interoperability between platforms. Currently, in contrast to balancing markets, there is no common European framework to ensure interoperability between flexibility market platforms. Such a framework will be important for scaling up flexibility market operations and liquidity. Although each SO could manage its necessities through its own platform, common platforms for DSOs and TSO could allow the access to more and diverse providers (43). In case of separate platforms, lacking interoperability could pose barriers for scaling up flexibility market solutions. For example, without such interoperability the automation of the prequalification process and potential to prequalify on several platforms would be more difficult to achieve. In turn this could limit the access to flexibility requested by SOs. More on the aspects of prequalification in Theme 4. Two main problems have emerged regarding the lack of standardisation to enable interoperability: (1) the communication among IoT and sub-metering and control devices (e.g., aggregator with appliances, etc.) as mentioned, (2) the interface between different systems and platforms (at DSO and energy asset level).

Standardised messages in terms of semantics and communication protocols between (TSO)-DSO-(aggregator)-FSP for when bids are procured and activated would be beneficial (Action-Recommendation 3.5). Currently, different communication protocols are needed depending on the type of FSP and market participant. This could become quite time consuming and costly for SOs as it makes communication with different types of FSPs and markets more complex to develop, implement, deploy, update, and maintain for every target system. If several separate markets exist and SOs develop their own approach to this matter it would reduce interoperability and increase complexity, ICT costs, and time spent for FSPs, leading to market entry barriers and potentially decreased liquidity.

At the same time, the formats for data output from the FSPs smart-meter might impact the potential for interoperability which is why formats for this output data should be standardised to ensure that it is possible to increase interoperability between regions and streamline interfaces of platforms (Action-Recommendation 3.4). In Sweden, smart-meter roll-out has commenced without such standards which causes issues for setting requirements on a national scale for data and metering as the formats for data output from smart-meters could differ between regions. In Greece a similar situation materialised where smart meter providers use proprietary software and unstandardised protocols to transmit data. Ultimately this will impact the potential for interoperability. *In this process of defining new standards, review of existing standards and payloads must be done to ensure that meta-data collection and attributes will be consistent with the needs of new flexibility products. This will lower the overall complexity and cost of integration (Recommendation-Action 3.5).*

The second issue to be solved to enable interoperability is the interoperability between market platforms. An investigation into the possible reason for the lack of interoperability between systems is reported in (104). According to this study, one of the main reasons is the nature of these technologies which require a highly specialised skill set and that platforms are often developed from a product-centric, bottom-up approach where the system perspective, top-down, is often neglected. Lacking interoperability can also be the result of trade-offs between the profitability of the business case, the strategic position for privacy and security considerations, and fulfilment of legal requirements (102). *A framework for the interoperability between grid components and market platforms should be developed with the future "Implementing Act in Data interoperability for Demand Side Flexibility" as a foundation. (Recommendation 3.5).* Here we have reason to return to another scheme developed by the Bridge Data Management Working Group (105). After an extensive survey across many EU funded projects in the energy domain, a European energy data exchange architecture was proposed (see Figure 14). This architecture, the Smart Grid Architecture Model (SGAM), was applied in CoordiNet deliverable 6.5 to visualise the different architecture needs in the demonstrations

(102). With the help of the SGAM, different interoperability levels could be investigated and standardisation possibilities as well as security risks could be analysed. This is a high-level reference architecture that considers the information flows that characterise energy markets and is based on the following cornerstones: interoperability, enabling free flow of data between platforms, enabling cross-border data exchange, accommodate any type of data, incl. real-time, sub-meter, TSO-DSO, etc., GDPR compliance, sector coupling, open source, standardisation needs, and exchange of data across projects. The SGAM proved an appropriate tool to include all different actors and systems in the different interoperability layers. The recommendations put forth in CoordiNet deliverable 6.5 mainly concentrate on the introduction of new standardisations for architecture requirements, new complexities of ICT, the integration of new flexibilities, as well as the integration of new IT security concepts. In this exercise, Common Information Model (CIM) and the Common Grid Model Exchange Standard (CGMES) were highlighted as possible standards for the information exchange between DSO and TSO.

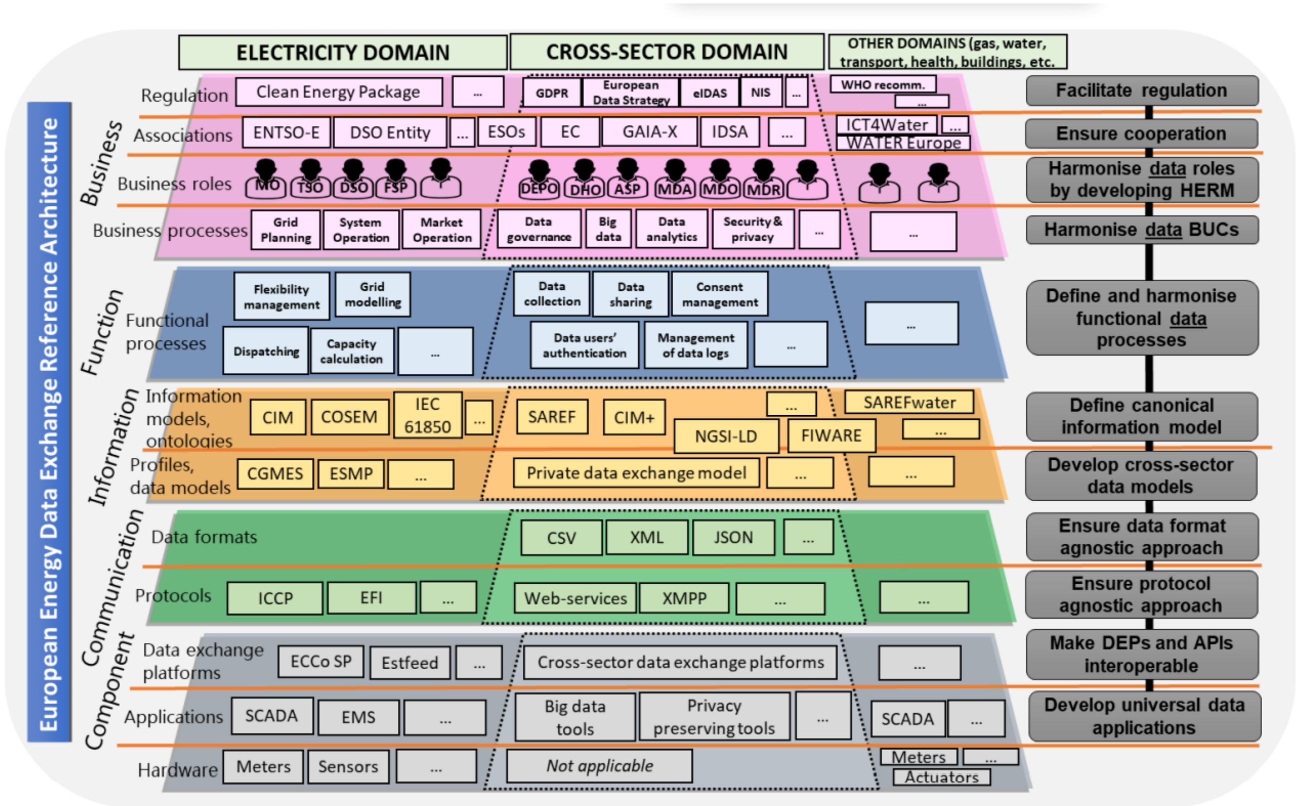


Figure 14. Proposal for a European energy data exchange reference architecture (105).

Even within demonstration pilots such as the CoordiNet test sites handling these data flows while managing IT-security and privacy issues was a challenge. The Swedish demonstration found that one of the most difficult and time-consuming aspects was data management and data security. Privacy and data security improvement processes were not easy and there is no standard established for security assessments of the information exchange between FSPs, companies providing services in the market infrastructure, and SOs. The amount of data gathered from consumers is increasing and the ownership and rules for the use of this data has not been defined. GDPR, data privacy, and ownership policies should consistently safeguard the developments of increasingly complex frameworks for data collection and sharing of information. To fully reap the benefits of this increase in information sharing, a secure mechanism must be in place that also allows consumers to access and manage their data to be able to accurately leverage their positions (106). In addition, to what extent data can be used without consumer consent should be further investigated.

As the complexity of the systems increase and if high levels of interoperability are achieved, such concerns of privacy and IT-security will become even more important to address. Interoperability as a requirement typically has an impact on IT-security and vice versa. Higher levels of interoperability would bring with it stronger requirements for encryption, secure protocols, etc. The new ICT control infrastructure and interfaces for controlling field automation create numerous new points of attack for third parties and vulnerabilities that could potentially be exploited. Security measures will in turn impact the latency, bandwidth, and speed of a connection link – and with it the overall costs. *Thus, security measures must be balanced with the increasing number of distributed flexibilities. As the number of interfaces rise so does the possible attack vectors in the grid (Action-Recommendation 3.5).* Here the analysis, and mapping onto the SGAM, performed within CoordiNet can act as a valuable reference for future risk analysis to pinpoint vulnerabilities within the system. In such analyses, the aim of balancing affordability, security of supply, and compatibility must always be taken into account. Such aspects will vary between Member States and will have a strong impact on the replication of flexibility control solutions based on national data and system requirements.

Insights from the demos: Sweden

Inspired by the Swedish CoordiNet demo a standardised product definition for flexibility has been developed (107). The work was launched during 2021 and is based on the IEC 62325 CIM mandated by European Commission in M490 for electronic market data interchange and message formats within the European Union.

For more information on the details of the proposed data exchange architecture, please see CoordiNet deliverable D6.5 (102).

4.3.3. Theme 3 Recommendations

Table 17. Theme 3 recommendations and list of actions derived from the CoordiNet demonstrations and analyses.

Recommendations	Actions	Level of implementation	Priority
3.1 Before defining standards for flexibility services, regulatory harmonisation of other processes and requirements should be done.	A common terminology for services should be developed and implemented on EU level, so that all Member States use the same definitions and terms.	EU	High
	General principles should be defined regarding competition, efficiency, and non-distortion, which are missing at the moment. A detailed regulatory framework should be defined by the Member State/NRAs.	EU & National	High
3.2 For congestion management, harmonisation, *aiming to reduce variations*, rather than standardisation, *defining single product values*, is recommended. Flexibility markets are too immature and in need of continued innovation.	For congestion management some general principles should be developed, such as a common list of attributes from which all Member States can choose the ones needed for national specific products.	EU & National	High

3.3 Coordinating markets and products that could provide several services is key for increased liquidity.	There must be an efficient coordination between different market requirements and flexibility services. This could increase efficiency of market participation as one product could fulfil several services.	National	Medium
3.4 Harmonisation of rules regarding gathering measurement data for an efficient and secure electricity system.	Efforts should be made to promote an accelerated deployment of monitoring and measurement tools to improve digitalisation and grid observability. The EU DSO Entity and ACER should perform an active role in monitoring the national implementation of the flexibility markets and highlight best practices in each Member State.	EU	High
	Formats for smart metering output data should be standardised to ensure that it is possible to increase interoperability between regions and streamline interfaces of platforms.	National	Medium
	To make smart meters data accessible and possible to use, standards for processes and power of attorney must be developed between the SOs and the FSP.	National	High
	Some minimum requirements on data should be established and implemented when harmonising products, such as granularity, accuracy, level of aggregation acceptable etc.	EU & National	High
3.5 A framework for the interoperability between grid components and market platforms should be developed with the future Implementing Act in Data interoperability for Demand Side Flexibility as a foundation.	Standardised messages in terms of semantics and communication protocols between (TSO)-DSO- (aggregator)-FSP for when bids are procured and activated would be beneficial.	EU	High
	Impact of legacy markets/systems of already implemented solutions should be evaluated and considered, as the cost of integration have a strong impact on the overall economic efficiency.	National	High
	Review of existing standards and payloads must be done to ensure that meta-data collection and attributes will be consistent with the needs of new flexibility products. This will lower the overall complexity and cost of integration.	EU	Medium
	Security measures must be balanced with the increasing number of distributed flexibilities. As the number of interfaces rise so does the possible attack vectors in the grid.	National	High

* Business
Techno-economic
Institutional and regulatory
"Social"

4.4. Theme 4: Adaptation of Market Phases for New Products and Actors

The Challenge: The development of new flexibility markets will result in new challenges in all market phases; prequalification, procurement and activation, and settlement, to adapt to new market participants and roles.

Key take-aways from the Coordinet experience:

Timing aspects and integration of new flexibility markets

Efforts should be put on integrating flexibility markets with already established markets and processes to not disrupt these, as well as making sure to minimise complexity for FSP to participate. The coordination between markets will be important to avoid overlapping which risks loss of liquidity. However, CoordiNet do not recommend standardisation of market timing on EU level as it depends on national and local context.

Prequalification

Harmonisation of requirements and processes for prequalification is desired across flexibility services and market platforms to increase liquidity and reduce complexity. CoordiNet highlight that, processes should be automatised to the largest extent possible. In addition, prequalifying for a service with more strict requirements could entail automatic qualification for services with less strict requirements. The demonstrations also highlight that other aspects, besides product requirements, should also be included in the prequalification process, such as a testing the communications between the FSP and the market platform.

Procurement and activation

Key factors impacting the implementation of flexibility markets in regard to procurement and activation are strongly linked to the quality and accuracy of grid representation in the market. Usually, the location or spatial dimension of the flexibility provider is not very important for the frequency-based products, as long as it is within the relevant control area and fulfils the technical pre-qualifications. However, the location of the flexibility provider is an essential factor for congestion management and voltage control. As a result, the optimal use of the offered flexibility in flexibility markets requires a critical assessment of network constraints and resource location needs. Insufficient grid representation in the market could thus impact pricing (due to sub-optimal bid selection) and lead to a violation of network constraints, as the matching between where in the grid issues have occurred and the location of the most appropriate flexibility resource is not taken into account in the bid purchasing process.

Settlement

How to best ensure that fair compensation is given based on activation and provision of service to the grid is a key factor for the establishment of a successful market. Currently, low observability in low voltage grids, due to lack of smart- and sub-metering data, will however make accurate settlement processes difficult to achieve. The settlement processes require the monitoring of several grid parameters and collection of their real-time telemetry measurements or calculated values, as well as baseline provision, as communicated by each service provider with the necessary granularity and frequency depending on the flexibility service in consideration.

As both the baseline as well as measurement data is the foundation for the verification, settlement, and subsequent payment for the delivered flexibility, transparency is very important. Lack of measurement data transparency can result in gaming as it becomes difficult to verify the delivery of procured flexibility from a specific market participant. Measures should be taken to ensure transparency in data exchanges necessary for settlement processes in flexibility markets to increase trust among all stakeholders. In some cases, this might call for an independent third-party performing this process, which could be subject to external auditing.

The establishment of new flexibility market also comes with the need to adopt market phases, processes, and methodologies to fit new characteristics that differs flexibility markets from already established wholesale and balancing markets. In addition, CoordiNet has highlighted the fact that the efficiency of the coordination schemes can be directly affected by entry barriers and differing requirements and product specifications between markets, when those occur. Hence, different coordination schemes may become more or less adequate in different instances depending on the prevalent practical settings such as, national grid characteristics, the design of the flexibility products and their specifications, and entrance costs to the markets. In the following the importance of the different market phases upon these relationships will be further explored.

This section will start with an overview of market timing and how the different demonstrations have integrated the flexibility markets with already existing wholesale and balancing markets. Thereafter, aspects of the market phases of prequalification, procurement and activation and settlement will follow, taking a closer look at how new market actors and flexibility products will affect the processes and what necessary adaptations are needed to establish new flexibility markets (Figure 15).

Figure 15.Market phases studied in stop 4 of the roadmap.

4.4.1. Timing aspects and integration of new flexibility markets

Timing aspects and integration of a flexibility market is important for all involved actors. Existing central wholesale markets and system operation are in general fairly synchronised. While there are minor shifts in spot market openings and closings, when comparing different regional implementations, it is of great interest, whether one can identify recommendations on how to integrate newly built local flexibility markets into existing processes. Even though the alignment between local flexibility markets with the EU wholesale and balancing markets may be challenging as they often take place in the same or overlapping timeframe. Setting flexibility market timeframes will have an impact on the activity of FSPs, i.e., market participants who have for instance large uncertainties when it comes to unit commitment. These actors would prefer shorter planning horizons. At the same time, when the utilisation of multiple markets is coordinated as a sequence of market windows, forwarding of bids could be realized which might affect again, first the economic attractiveness of the flexibility market but also the liquidity in all connected markets.

From the SOs perspective the timing of market closure affects the time used for evaluation of grid status, also taking into account results from earlier energy market sessions. To identify any risks or potentials and formulate first steps that need to be taken for a future market design with coordinated wholesale and balancing markets that can access flexibility in all levels, the current state, regional regulations, and potential barriers need to be identified.

When looking at the experiences from the CoordiNet demos, two alternatives for integration have been tested for a local congestion management flexibility market, before or after the wholesale spot market. The timeline for the incorporation of the different markets can be seen in Figure 16.

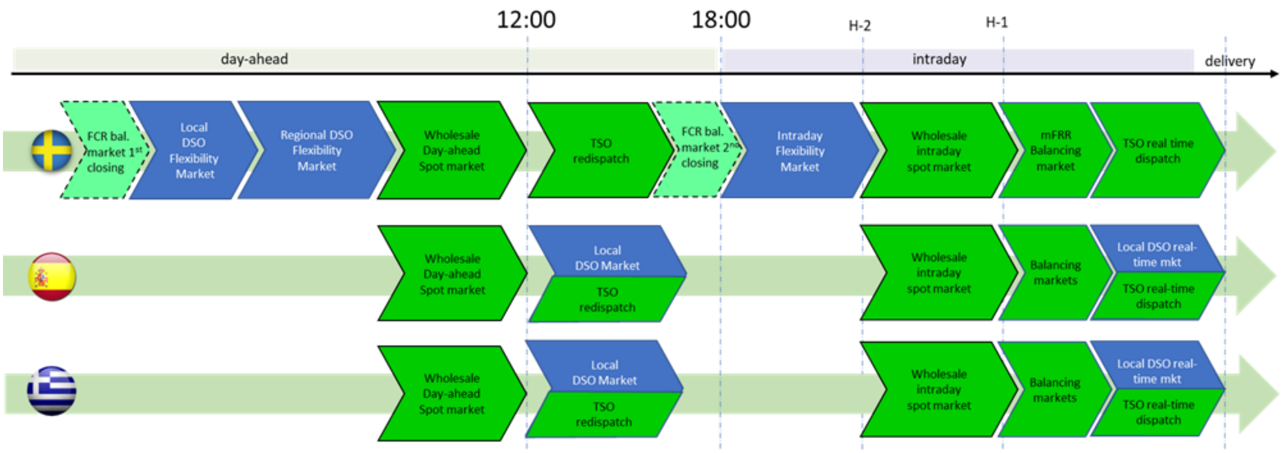


Figure 16. Integration of the CoordiNet markets with European wholesale and balancing markets (65).

The CoordiNet project does not recommend standardising market timing on EU-level as it depends on national and local context. However, effort should be put on integrating flexibility markets with already established markets and some high-level principles can be recommended (Recommendation 4.1), including:

- *To enable FSPs to participate and stack value over several markets, overlapping clearing times should be avoided as this can have a negative impact (Action – Recommendation 4.1).*
- *The SOs should arrange local congestion management and voltage control markets taking into account the timing of already established balancing markets to not disrupt the security of the system (Action – Recommendation 4.1).*

In the following sections, some examples of how the aspects of market timing have been approached in the CoordiNet demonstrations will be presented.

4.4.1.1. Integration of local congestion market before the wholesale market

In the Swedish demo a multi-level DA local flexibility market for congestion management is implemented. The market is defined by closed gate auctions and situated before the DA wholesale market closing at 9:30 am CET, after which, uncleared bids can be forwarded to the local/common flexibility ID, central ID and lastly to the TSO mFRR balancing market. The Swedish demo also tests a local ID congestion management market defined by closed gate auctions that is open until 2h before real-time operation (45). This ID market helps the DSO to adjust the grid status after the interactions of other FSPs in the DA wholesale market. The closing of the market was determined since the Swedish TSO indicated that flexibility should be cleared with at least 2hrs margin not to disturb the balancing market. From the DSO perspective they could theoretically clear until delivery time, but as most FSPs want to know with good margin, preferably DA, whether they will be activated or not, the Swedish DSO has accepted this timeline as a compromise to have enough flexibility available, which generally gets lower as closer to real time operation it gets (33).

4.4.1.2. Integration of local congestion management market after the DA wholesale market

In the Greek and Spanish demo, local congestion management markets have instead been implemented after the DA spot wholesale market, closing at 2:30 PM CET and at 23:00 in Greece (28).

The Spanish demo chose this timing because the common congestion management market tested in CoordiNet is an extension of the already existing congestion management market for transmission system, by considering also the DSO requirements at sub-transmission level. This common market is also a closed gate auction with CGT 3PM CET of D-1. The market clearing process is composed of two different phases, in accordance with the current congestion management market (28).

The demonstrations also have ID local congestion management markets: the Spanish clearing 30 minutes before each market session delivery time and the Greek ID multi-level and fragmented congestion management market closing at 8 am CET before the ID wholesale energy market (28).

A market closing after European wholesale markets allows market participants to have a baseline compatible with the wholesale market results, as well as enables using the DA market results to make an accurate forecast of the flexibility needs by the SO. The Spanish demonstration also highlights that, to avoid speculation, the flexibility offers should be submitted only after the baseline for the FSP is published, and, subsequently, the DSO publishes the needs to be met. Then, speculative offers would not be possible (47). The Swedish demo is adding that the ID flexibility market solves this problem (33).

4.4.1.3. Integration of local congestion management markets closer to real-time operation

Very close to real time, after closure of ID options, only the TSO could further make use of short-term flexibility options, since this goes into the system security responsibility that directly relates to balancing (108). It shall be noted that the TSO has several products that are not offered via the ID market which can be utilized for congestion management. Often these products are traded into the operating period.

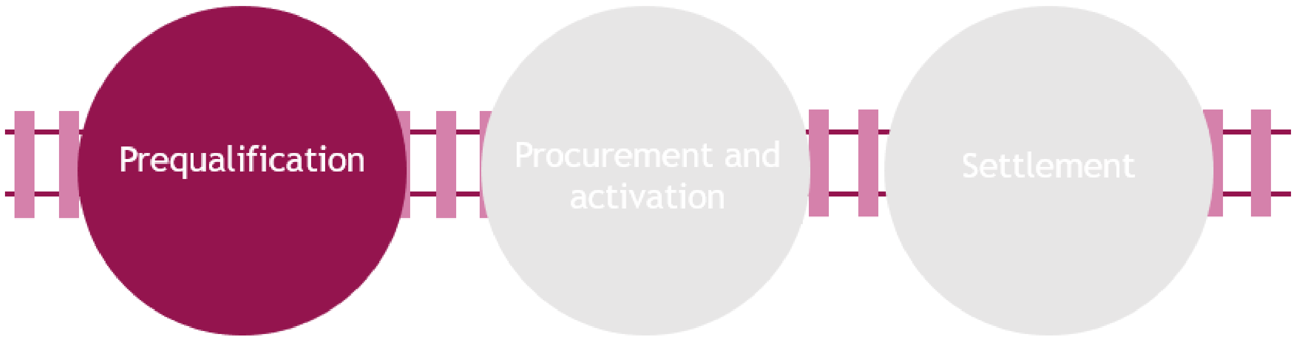
In CoordiNet two real-time markets for local congestion management were tested in Spain and Greece, having their gate closure time at H-30min and H-15min respectively (28).

As described in NODES white paper *Paving the way for Flexibility* from 2020, in most European countries there is still a period between ID gate closure and the actual operation, which is referred to as "grace period" where both DSOs and TSOs can manage rebalancing and congestions with the certainty that the balancing parties will not cause countertrades yet (109). For the case that other markets would clear closer to real time, (110) points out issues which may arise: The longer the market options are open the later the TSO and DSOs can use the time to evaluate the overall energy system status, to eventually trigger reserve deployment or ancillary service market offers. Here, recommendations are given that through investments in ICT solutions, the computational time for market clearing can significantly be reduced to allow a shorter-term flexibility bidding and active system operation. Article 59 of the Regulation 2015/1222, guideline on capacity allocation and congestion management (CACM) states that:

> “The intraday cross-zonal gate closure time shall be set in such a way that it: a) maximises market participants' opportunities for adjusting their balances by trading in the intraday market time-frame as close as possible to real time; and (b) provides TSOs and market participants with sufficient time for their scheduling and balancing processes in relation to network and operational security.” (111)

However, how to coordinate the timing of new markets, with already existing wholesale and balancing markets, will be challenging, especially when attempting to establish pan-European flexibility markets.

4.4.2. Prequalification



As stated previously, the balancing markets are to a further extent regulated in comparison with flexibility markets, which also goes for the prequalification requirements. Regulation 2019/943 establishes, as a generic premise, that the market for procurement of balancing capacity shall be non-discriminatory between market participants in the prequalification process (13). With that purpose, Directive 2019/944 in its Article 40.4 details that the TSOs shall procure balancing services ensuring the participation of all market participants (83). To this end, the regulatory authorities and TSOs shall establish the technical requirements for the participation in those market.

More specifically, according to Regulation 2017/1485, the prequalification term refers to the process to verify the compliance of a reserve providing unit or a reserve providing group with the requirements set by the TSO (112). This Regulation addresses the specific prequalification processes for the FCR (Article 155), FRR (Article 159) and RR (Article 162) balancing services. Although this Regulation determines the general basis of how the prequalification processes must be developed, it is the responsibility of each TSO to develop the specific prequalification process, the details of which must be made publicly available. However, the mandatory minimum technical requirements for these three services are clearly defined in Articles 154, 158 and 161 of the regulation. The Directive 2019/944 also indicates that the prequalification process shall be a non-discriminatory process regardless market agents participate individually or through aggregation (83).

In the specific case of the congestion management, although the harmonisation at European level is not required, balancing and congestion management should be sufficiently aligned to allow an efficient market-based allocation of flexibility (59). The CoordiNet demonstrations highlight that different requirements and processes for prequalification between services will increase complexity of market participation for FSPs and access to services for SOs (33,40,47). The simplification and automation of prequalification processes has the potential to facilitate the scaling up of flexibility markets. To this end, a minimum level of standardisation and alignment of the process at European level for the different flexibility products has the potential to relieve market access barriers and benefit the fulfilment of the non-discrimination requirement (59).

TSOs and DSOs agree that the system operator managing the prequalification process should be the one who needs the product and buys it. However, when multiple system operators need the same product, the pre-qualification process should be agreed among both parties, in order to avoid repetitive processes (59). *Harmonisation of requirements and processes for prequalification is desired across flexibility services and market platforms to increase liquidity (Recommendation 4.2). The CoordiNet project also highlights that, processes should be automatised to the largest extent possible. In addition, prequalifying for a service with more strict requirements could entail automatic qualification for services with less strict requirements (Action – Recommendation 4.2).* The general process of prequalification can be separated in two parts. Firstly, a grid prequalification, meaning the evaluation of the electricity grid capacity to ensure that proposed FSP can connect specific assets to the grid correctly and in a secure way, and as well what impact the FSP might have on solving the grid issues it prequalifies for. An example of this will be discussed in the coming sub chapter of procurement and activation. Secondly, following the grid prequalification, a product prequalification is done to ensure the qualification of assets for providing specific services to the respective market (2). *To reduce the risk of excluding FSPs from markets, certain requirements could be checked ex-ante activation as a part of system prequalification of minimum necessary requirements. Product requirement could be checked in connection to the real activations, to ex-post validate that the unit is able to provide the specific product needed. If the validation is positive, the prequalification can automatically be renewed (Action-Recommendation 4.2).*

As mentioned in theme 1 and 3, the Electricity Directive, Article 32, addresses the market-based procurement of flexibility by the DSO (14). It states that when incentivising the use of flexibility in distribution networks, the DSOs, subject to approval by the regulatory authority, shall establish the specifications for the procured flexibility services and, where appropriate, the standardised market products, at least at national level. This is important in order to avoid too many diverse products and specifications, especially when taking into account local considerations. This issue of homogenisation of flexibility products is directly linked to the prequalification process. The use of different requirements and prequalification methods by each country may represent a barrier and it could limit market access. This problem could be eased by deploying a certain level of standardisation (56). *CoordiNet therefore recommends that, prequalification requirements for flexibility services at distribution level should be fully included in the upcoming Network Codes (Action – Recommendation 4.2).*

When defining technical requirements, it should be strived for to not set them too strict and to make sure to cover all technologies that can deliver the service. With this said, in this process it will be important to analyse the potential need for adapting requirements to fit different types of technologies. For example, strict, data-demanding prequalification requirements, such as high granularity of measurement data, risk increasing equipment costs and management times, result in a reduced margin of profit for FSPs. Also, in the case of aggregation of small-scale units, the technical requirements established to prequalify for existing markets may pose a strong barrier for both aggregators and small DER to participate in them. In deliverable D6.6, the Spanish demonstration indicates that cascading funds were used to allow FSPs to upgrade their current installation to fulfil the necessary requirements (64). *Hence, requirements in the product prequalification process for market participation should not be too strict but should be set with a broad set of FSPs in mind. Such requirements should however include conditions regarding reliable real-time measurements and provision of baselines to prevent gaming (Action – Recommendation 4.2).* Below is an example of how the Spanish demonstrator has lowered the requirements for small FSPs.

Insights from the demos: Spain
To facilitate the data exchange for flexibility purposes, independent monitoring devices are used by aggregators, such as the EnergyBox deployed in the Spanish demonstration. This way, the burden on the small FSPs can be reduced, and requirements for their participation can be made less strict. This would also allow the aggregator (or DER) to freely choose the communication protocols for their link, which would enable competition in this field and the development of more efficient alternatives. Additionally, the communication between the SO and DER would be simplified, as the latter would be aggregated, reducing the communication links involving the SO (87).

The CoordiNet demonstrations highlight that standardisation of prequalification attributes such as format of power of attorney, baseline methodologies, FSPs impact on the grid, grouping of FSP after their geographical grid location and asset information needed on the FSPs, are of specific importance (33,40,47). The demonstrations also highlight that other aspects besides the product requirements should also be included in the prequalification process, such as testing the communications between the FSP and the market platform.

4.4.3. Procurement and activation

In the same way as for the prequalification process, the procurement and activation are also regulated and to a lager extent harmonised for balancing services. For new flexibility markets as congestion management and voltage control the case is not the same. According to the European Regulation 2019/943, the clearing of balancing energy products, both standard and specific[14], shall be based on marginal pricing (pay as cleared) (13). However, the possibility exists to propose a different approach (e. g. pay-as-bid). The approach would have to be approved by all regulatory authorities on the basis of a joint proposal demonstrating that the alternative pricing method is more efficient. In general, as stated in Onenet's overview of market design for procurement of system services, this approach of marginal pricing is the predominant option for most of the current projects analysing the flexibility provision for the frequency regulation (e.g., CoordiNet, INTERRFACE, FARCROSS, etc) (113). However, there are several projects in which alternative options, such as pay-as-bid (e. g. OSMOSE, TDX-ASSIST), are being considered. Insights from the demos regarding the pricing scheme can be seen below.

[14]According to (13): Standard balancing product: A harmonised balancing product defined by all transmission system operators for the exchange of balancing services.
Specific balancing product: A balancing product different from a standard balancing product.

Insights from the demos: Sweden and Spain

Spain: The CoordiNet demonstrations highlights in their conclusions that marginal pricing has been used to be more efficient. An example of this comes from the Spanish demonstration where the congestion management in Spain is developed in two stages; a unique marginal price is applied in the first stage and a pay-as-bid approach in the second stage. CoordiNet deliverable 2.1 states that the pay-as-bid approach, where the bids reflect the true variable production costs, are not efficient price signals, since the energy is not priced at the opportunity cost for the system, and it does not reflect the real value that this energy has for the system. Deliverable 2.1 also identifies that the price mechanism applied in this case could not be fully aligned with the European guidelines. The price applied in the first stage does not reflect the congestion existing in the grid, so, this price does not reflect real supply conditions in each area of the system, as energy prices should. For that reason, as conclusion, D2.1 proposes the application of the marginal price approach in Spain in order to be more efficient **(28)**.

Sweden: Other experiences from the Swedish demo highlights that when evaluating the available bids, it is important to distinguish between two different price levels corresponding to two different business cases. One for peak-shaving when it is cheaper than the overlying subscription cost, specific for the Swedish case as the DSO has a subscription level to the overlaying transmission grid that works as a breaking point for when the DSO buys flexibility or not, and one for peak-shaving when the grid situation is unnormal. This is referred to as low and high price bids. A complicating factor in the evaluation is the fact that some FSPs place bids only after communication from the buyers that bids are needed **(65)**.

In the case of congestion management, even though the service is not harmonised at European level (i.e., different rules may apply in each country), Regulation 2019/943 establishes in its Article 13 several general principles for the redispatch of resources that should be fulfilled by the Member States (13). Among such principles, the Regulation states that the resources that are redispatched shall be selected from generating facilities, energy storage or demand response using market-based mechanisms and shall be financially compensated. Regulation 2019/943 also states that the adoption of non-market-based redispatch mechanisms is possible only under very specific situations (13). However, it does not specify how the market should be arranged, neither the market clearing process or optimisation function for the development of a specific algorithm that would ensure fair pricing and activation mechanisms, nor the prices to be applied.

To ensure a well-functioning market and pricing mechanisms for congestion management, some general principles should be defined at EU-level regarding competition, efficiency, and non-distortion, which are still missing. However, CEER highlights that the detailed regulatory framework should be defined by the Member State or the NRA and be consistent with national provisions and national practices (29).

The implementation of higher share of DERs might also create new issues when clearing the market. What may imply a risk in the new ambit of higher share of DERs and inclusion of assets connected to the distribution voltage level for delivering types of services such as balancing and congestion management is that: existing bid structures and clearing mechanisms are insufficient for taking into consideration the risk of FSPs not being able to supply contracted energy as the rate of DER deployment and variability in the FSP portfolio increases. However, new mechanisms to mitigate this problem are under research (96). One of the proposed solutions is the implementation of probabilistic offers (i.e., quantity, price, and risk level) and there are already several works considering new stochastic market clearing algorithms accepting probabilistic flexibility bids (96). In their literature review, Villar, Bessa, and Matos, also indicate the geographic dimension as a relevant issue in which efforts for increasing the flexibility incorporation is needed (96). Within this specific geographic topic, authors identify the necessity of a higher level of harmonisation of the market clearing mechanisms and propose the nodal-price approach to improve congestion management. This is not furthered investigated in the CoordiNet demonstration but could be a topic for future projects.

4.4.3.1. Procurement optimisation and pricing

As mentioned in Theme 1, depending on the choice of the coordination scheme different procurement optimisations will be applied, where two main possibilities are identified; i) centralised optimisation, in which a single algorithm performs the optimisation for the transmission and distribution level considering constraints at both levels, and ii) decentralised optimisation, in which the optimisation is performed separately for each level by the SOs (or independent market operators), who must be coordinated. Both options have their pros and cons.

Besides the choice of coordination scheme and thereby optimisation algorithm, a main objective for market clearing optimisation is to maximise social-economic welfare, or minimise the total procurement cost. The optimisation process used in CoordiNet is the minimisation of flexibility purchasing costs (minimise the supply costs) (28). Minimising the costs of purchased flexibility leads to meeting the system needs at least possible cost, which in turn leads to reducing electricity bills of customers. Smartnet reports that, although the goal of energy markets is to optimise system welfare, in the case of balancing and congestion management markets, SOs targets should be to buy the minimum amount of system services perturbing as little as possible the results of the energy markets (44). Likewise, Onenet identifies the same main market clearing optimisation objectives (113). In the literature, two different objectives are defined for market clearing optimisation: (1) maximisation of the social welfare, and (2) minimisation of activation costs (44). However, in the markets studied in CoordiNet, maximisation of social welfare and minimisation of costs for procuring of flexibility often amount to similar results of increased social welfare and are seen as equivalent.

The determination of the activated flexibility should consider not only the price of the submitted bids but also their impact on the reliable operation of the system. As an example, looking at specific products, the procurement of many capacity products by TSO and DSO involves availability prices that are fixed over long temporal intervals, often months-ahead or weeks-ahead. The economic value of capacity products however depends massively on system conditions that change in much faster timescales. This can result in over- or under-procurement of capacity products. The CoordiNet consortium thereby recommends that this could be resolved by using reserve markets closer to the time of operation (e.g., week ahead or day ahead). Forecasting tools often play a role on this level as mentioned in Theme 1. Time series of forecasted data serve as inputs both to identify potential constraints for more targeted flexibility procurement, for remedial actions such as preventive redispatch and balancing but also for general monitoring and validation.

4.4.3.2. Network representation and geographical scope

Transmission and distribution networks impose technical constraints, such as line flow and voltage limitations, on energy trading. These constraints should be considered in energy markets to ensure the reliable and secure operation of power systems. While the provision of flexibility from a certain flexibility provider might be profitable from an economic perspective, it might cause the violation of network constraints (114). As previously mentioned the responsibility of ensuring grid security and stability lies with the SOs. CoordiNet therefore recommends that the *responsibility for determining the methods for bid selection should remain with SOs as the responsible agents for grid management. This method should be defined in a transparent way to ensure trust in pricing and market operation (Action - Recommendation 4.3).* Defining such methods lies beyond the scope of this roadmap but we direct the reader to CoordiNet deliverable D3.7 (87), D4.7.1 (65), and D5.7 (115) for information on how this was done within the different demonstrations as well as in deliverable D6.3 (35) where the topic of bid selection and clearing mechanisms has been included in the coordination scheme analysis of the different BUCs.

Additionally, depending on the service procured, the local relationship between the technical problem to be solved and a specific flexibility provider affects the effectiveness of the provided flexibility in solving the specific problem. A network representation, considered when clearing the market, could solve this.

When including a network representation, it is important to find the right level of detail. A full network representation would not only slow down the clearing process as this would include much more data and a likely added complexity to the market clearing algorithm, but would also add requirements on the SO to send grid data to the market operator (if not market operator themselves). This would imply sharing sensitive data. In addition to that the data is sensitive to share, the state of the grid changes dynamically. Hence, the network state (which is not only its topology, but the voltages, flows, injections, offtakes, etc.) changes continuously and rapidly. Hence, the updated network representation has to ideally also capture this element, which can be challenging in practice due to the trade-off between exactness of the network representation and the available time requirements and capabilities of repeatedly and frequently generating and sharing network information. The grid state is sometimes also not fully available to the operator, in case, e.g., not enough measurement units are available in the system. The CoordiNet project recommends the *inclusion of simplified network representation in the market clearing to ensure that network limitations are not violated and enable both TSO and DSO to select the bids that most efficiently solve the issue at hand (Recommendation 4.3).*

In general, the effectiveness of a bid meeting a certain flexibility need, depends on network topology, system state and type of the problem to be solved, thereby meant the service to be provided. Hence, the location of the flexibility provider is fundamental for market clearing (116). Thus, a location tag is necessary for some products. Usually, the location or spatial dimension of the flexibility provider is not very important for the frequency-based products, as long as it is within the relevant control area and fulfils the technical pre-qualifications. However, the location of the flexibility provider is an essential factor for congestion management and voltage control (117). As a result, the optimal use of the offered flexibility in flexibility markets requires a critical assessment of network constraints and resource location needs (118).

Insights from the demos: Sweden

The primary goal of the Swedish flexibility markets for congestion management is the set-up of correct arrangements to guarantee an efficient market operation for DSO grid needs coordinating with existing markets – all in a manner that is technical feasible today. In Sweden the existing flexibility providers mainly exist in rural areas and the DSO grid need exists in urban cities where there today is no existing flexibility from TSO markets to share with DSO grid needs **(65)**.

Using a network model in market clearing, the network constraints are explicitly incorporated in the clearing process, improving the efficiency of the market, and leading to the most cost-effective procurement of flexibility, while ensuring that all network constraints are met. That would also be the case beyond congestion management. For example, a market in which the TSO accesses flexibility bids submitted from resources connected at lower voltage levels, would need to make sure that this resolves the issues for the TSO without causing additional issues in the distribution grids. Similarly, congestion issues resolved at the distribution level, must also abide by the network limits of the overlaying grids (i.e., the transmission level). Without a sufficient representation of network topology in the market clearing process it will be a challenge to accurately select bids that most efficiently solve the grid problem. This lack of topology representation could impact pricing (due to sub-optimal bid selection) and lead to a violation of network constraints, as the grid impact is not taken into account in the bid purchasing process. The used network model should ensure that the network constraints are not violated when clearing the market and that the existing network issues are solved, given that there is enough flexibility to solve them. The model cannot be too complex to keep the problem computationally tractable, but it cannot be very simplified since critical network constraints might not be taken into account.

The complexity of the problem depends on the type and size of the network, as well as on the method for calculating the key network operational parameters (such as power flows, and voltages, among others), known as the power flow calculation. For instance, when a large area of the transmission network is addressed, thousands of transmissions lines might be considered slowing down the computational process that can lead to unacceptable execution times (119). Besides the grid topology, this also depends on the number of grid violations to solve at the same time, and the way these violations are computed and checked. If the optimisation aims to solve hundreds of congested areas, while including complex network representations, the optimization might not converge in the allocated time, which highlights the benefit of using a simplified representation. Complex clearing algorithms, as a result of including complex network topology representation or optimisation of several grid needs, cause long computational times which risk shortening the "grace period" of the TSO and DSO. Too little time to control and evaluate grid status after the market clearing could risk compromising the security and stability of the overall system. *The inclusion of network representation has to be done while keeping the complexity of the clearing algorithm down, thereby keeping computational complexity low and ensuring fast clearing times but while adequately ensuring the security of the network operation of all the grids involved (Action - Recommendation 4.3).* Simplified network representations, as tested in the demonstrations, could be used (for example, linear network models or impact factors) to keep the computational complexity of the clearing algorithms manageable. They describe the influence of unit flexibility activation on network variables, such as power flow along a line. Their values depend on the current system state. Therefore, their proper and accurate calculation is of high importance, otherwise small perturbations could have a significant effect on the system operation, leading to non-solution of the existing problems and/or to the emergence of new ones (28), (120).

The simplified methods used in the demonstrations includes static and dynamic impact factors, where this is applicated over the bid price when clearing the market. The impact factors were already evaluated and set in the grid prequalification phase of each FSP. Simplified topology representation methods that are applied on top of the market price, such as impact factors tested in the demonstrations, might create transparency issues, and might meet resistance from FSPs. In the specific case of the analysis of the Swedish demonstration and the business use case of SE-1a (multi-level congestion market), the main findings are related to the importance of the accuracy and transparent calculation of the impact factors to be considered in the market clearing mechanism. The sensitivity analysis performed shows that a low variation in the impact factors may imply high variability in the total system costs and the revenues to be perceived by the FSPs (28). *CoordiNet therefore recommends that, an impact assessment is done for methods to include network representation in the market clearing to ensure sufficient description of the grid (Action - Recommendation 4.3).* It is also important to make this process transparent towards the FSPs. The use of impact factors in the different demos can be found in Table 18.

Table 18. Summary of how impact factors have been applied in the CoordiNet demonstrations.

Demonstration country	Approach to network representation
Sweden	In the Swedish demonstrator, the impact factors for congestion management have been calculated based on the winter peak load scenario when the subscription level violations are expected to occur. The dynamic calculation of the impact factors would require third parties' access to system parameters that are considered as classified information in Sweden due to security reasons (21). In the long run a power flow calculation with the forecasted grid situation might be required, which would in effect require the platform to have a digital twin of the grid and possibility to hold the solution to the impedance matrix between major connection points to calculate more specific impact factors. Integration to SCADA with this functionality could be another option.
Greece	In the Greek demonstrator, the impact factors have been calculated taking into account the radiality of the distribution network. Ignoring the losses, the impact factor for congestion management is equal to one when the FSP is downstream of the examined line and zero otherwise (21).

	In the Greek demonstration network information is included in the form of sensitivity matrices for both congestion management and voltage control in the local market, i.e., voltage sensitivity factors for voltage control market and Power Transfer Distribution Factors (PTDF) for the congestion management market. More information on the creation of sensitivity matrices for congestion management and voltage control can be found within D5.7 (115).
Spain	In the Spanish demonstrator one solution adopted is the use of impact factors for the local market formulation (87). A detailed representation is also used in the Spanish demonstration. The provision of flexibility by small FSPs will call for the exchange of data regarding their electricity usage in some form, so that flexibility provision can be verified and settled. One solution to facilitate this data exchange for flexibility purposes is the use of independent monitoring devices by aggregators, such as the EnergyBox deployed in the Spanish demonstration. Increasing the observability of the LV distribution grid is crucial to monitor the grid status and improve the process of detection and solving of local congestion. To this end, 108 MV/LV secondary substations (including more than 130 transformers) have been updated by installing sensors at the LV side of the transformers, facilitating the correct management of the local network congestion tested in Malaga (87).

However, as these markets grow, and the number of participants and bids grow, it would become increasingly challenging to be able to have such a pre-qualification mechanism to guarantee the safety of the activation of any subset of bids without including a highly restrictive (and, hence, costly) prequalification mechanism, that would prevent the valorisation of the capabilities of distributed flexibility resources in providing system services. As such, the inclusion of such network information limitation in the market clearing may require the additional burden of information sharing but would have a significant impact on improving the operation of the grid, integrating more flexibility resources (and distributed renewable energy resources), and improving the optimality of the markets involved (21).

From the SOs perspective, as mentioned, the main challenges to include a network representation in the market clearing is the network information sharing necessary. A full network topology representation is dependent on high amount of data to be shared between actors. How to manage these data flows to properly maintain the integrity, confidentiality, and security of the grid, without compromising market transparency, is an important challenge to overcome. This stem from: 1) confidentiality issues, and 2) the need to replicate network databases in different servers (which can be practically challenging and can also face security constraints) (21). Detailed structural grid information is confidential and the core business of DSO and TSO, and this data can be sensitive to share. Sharing this type of information also implies an important administrative burden: defining templates to share data and recurrent update of grid information. This topic has been extensively addressed in deliverable D6.2 (21), in which two solutions can be proposed. Firstly: variations to coordination schemes can lead to meeting their needs without the requirement of network information sharing. As an example, in local and multi-level markets, where the DSO is involved in the selection of the DERs that can contribute, it is not needed to share this information which eliminates this risk (47). Secondly, the use of aggregation mechanisms and aggregated data can reduce the sensitivity of the shared data. The aggregation techniques are furthered presented in deliverable D6.2 (21). The risk with this method is that it does not always lead to a complete representation of network constraints, which are needed to ensure that any market clearing leads to no violation of network constraints.

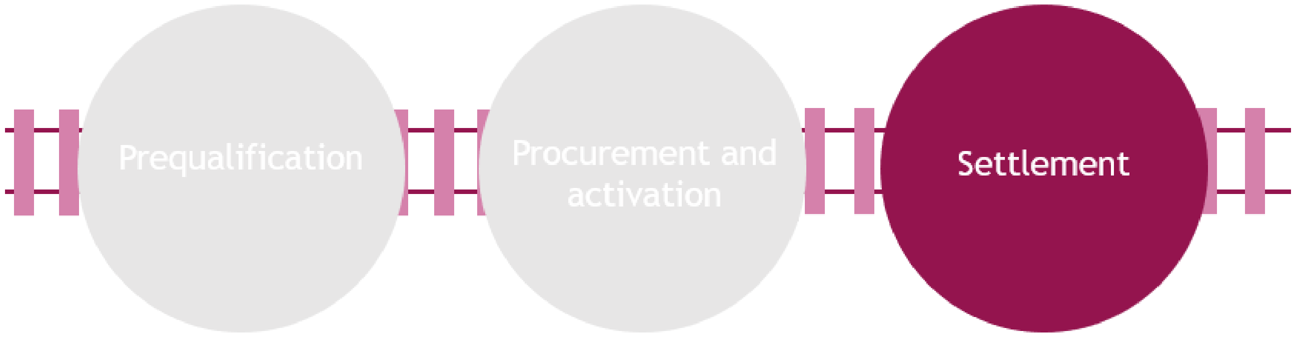
Going back to variations to coordination schemes, deliverable D6.2 (21)also looks closer into an example of a multi-level coordination scheme composed of three layers compared to the original two. By adding one additional market layer to the multilevel market model, without requiring any network information sharing between the DSOs and TSO, the market clearing is guaranteed to abide by all network limits (of all the grids involved on the transmission and distribution levels). By first neglecting constraints on lower-level layers, the clearing can lead to the violation of operational limits of the distribution network. To resolve such violations, a third layer is added to the clearing process, which includes only distribution systems. In this layer, each distribution system implements a redispatch to resolve any operational issues caused by the clearing of the second layer. This concept can achieve a market clearing without risking new congestions while it does not require any network information sharing. The proposed scheme is indicated as an interesting, future coordination scheme in the CoordiNet project to be explored further. This multilevel coordination scheme requires having enough liquidity in the flexibility market to be able to run the three layers of the scheme. However, given the assumption that these markets are expected to mature in the future with higher achieved liquidity, and since the market clearing problems can be kept linear by nature (hence, can be cleared efficiently in a time-restrictive manner), these two drawbacks should not be challenging to overcome (21). In addition, as developed in Marques et. al. distributed optimisation techniques can be implemented to clear the flexibility markets (such as the common and the multilevel markets) in a distributed manner, leading to no need of sharing of network information and to the ability of achieving an efficiency that converges to the centralised common market efficiency (i.e., the theoretically best solution) (121). However, this distributed optimisation process can face practical challenges due to their iterative communication needs among the different SOs.

A conclusion reached in deliverable D6.2 (21) is that, although the incorporation of network limits in the different market clearing processes can imply additional sharing of information and more burden for the clearing process, the market efficiency considerable improves. The importance of this issue has also been verified in the deployed demonstrators. Moreover, in addition to the inclusion of the physical limits of the distribution system as part of the market clearing, a good market mechanism should allow the derivation of an adequate, consistent, and optimal pricing mechanism enabling a competitive and fair remuneration for market participants.

4.4.3.3. Prevention of gaming

“Gaming” the market means placing bids for a higher profit, independently of their true cost or value, which results in higher procurement costs for the system operators. If FSPs act as rational and behave strategically, they have opportunities to “game” the markets, and the impact depends on many factors: the coordination scheme (local, common, fragmented, multilevel), the network topology, the grid constraints, and the number/placement of FSPs within the systems. As an example, it was shown that congestion can generate market power, including monopolistic behaviour, if parts of the system are isolated, and their needs must be fulfilled locally by a small number of FSPs. For example, the locational component of congestion management services could impose natural restrictions on market liquidity which could lead to concentration of market power and gaming as few resources can mitigate the congestion. This aspect has an impact on any type of coordination scheme studied. Therefore, the grid constraints combined with the number/placement of FSPs are points of concern and must be monitored when implementing the coordination schemes. Therefore, system operators must be aware of their network topology and grid constraints while market operators must encourage FSPs participation. Both are important to: 1) avoid market power in specific areas of the network; 2) guarantee market liquidity to reduce bid prices; and 3) avoid a great loss in efficiency by collusion and other strategic behaviours (21). The CoordiNet demonstration highlights that lack of set requirements for reliable real-time measurements and baselines already in the prequalification process poses challenges for gaming, something that will be discussed more in detail in the next section.

4.4.4. Settlement



To secure an accurate and transparent settlement process, new flexibility markets still have aspects that need to be developed. Balancing markets, as mentioned before for prequalification, procurement, and activation, already have several guidelines to follow that are still lacking for flexibility markets. *Harmonisation of settlement processes in European flexibility markets should therefore also be strived for (Recommendation 4.4).*

As already discussed in Theme 3, aspects of information sharing are of great importance to address to ensure a well-functioning flexibility market. This is again exemplified in the market phase of settlement where main barriers for implementation are connected to transparent sharing of information and data and the need for coherent methodologies of obtaining baselines from FSPs.

Regarding measurement data, the settlement processes require the monitoring of several grid parameters and collection of their real-time telemetry measurements or calculated values, as communicated by each provider with the necessary granularity and frequency depending on the flexibility service in consideration. As a consequence, the accuracy of these measurements has a direct impact on imbalances calculations and the overall flexibility procurement process. *Harmonisation of settlement processes is contingent on realisation of actions described for data and information sharing/product specifications regarding telemetry requirements (Action-Recommendation 4.4).*

As both the measurement data, as well as the baseline is the foundation for the settlement and payment for the delivered flexibility, transparency is very important from the FSP perspective. It is of importance to provide fair compensation accurately and transparently to FSPs for their supply to the market. Measures should be taken to ensure transparency in data exchanges necessary for settlement processes in flexibility markets to increase trust among all stakeholders. The other side of the same coin is that this transparency is also needed to guard the market from gaming activities that would push the market pricing and settlements in the favour of FSPs. *Verification of delivered flexibility requires a transparent settlement process. In some cases, this might call for an independent third-party performing this process, which also could be a subject to external auditing (Action-Recommendation 4.4).*

The demonstration highlights, that for not being able to deliver the flexibility procured in the flexibility markets, the new framework should be careful with the definition of any heavy penalties for FSPs not being successful to deliver the flexibility. As the future energy system has an increased share of intermittent generation and DERs with difficulties to forecast their exact load which will more likely be based on estimations, strict penalties may be a fear and thereby barrier to engage in the markets for many FSPs. This may risk the overall market liquidity and longevity of flexibility markets, at least in this early stage of their development.

4.4.4.1. Baseline methodologies

Considering that flexibility provision can be defined as the possibility of modifying generation and/or consumption patterns in reaction to an external signal (96), a key component for flexibility-related products is a basis for comparison, allowing the product buyer (e.g. the DSO) to verify if the FSP indeed modified their consumption/generation in accordance to what has been contracted (e.g. power reduction of X kW during Y hours). As stated previously, this basis for comparison generally exists for bulk generation individually committed in energy markets which is not the case for DER. Small DERs are usually represented by BRPs in wholesale markets in an aggregated manner, and therefore no individual consumption and/or production commitments exist. Without a defined methodology for provision of baselines from FSPs, a transparent and fair settlement process for both SOs and FSPs would not be possible. The demonstrations of the CoordiNet project stress that challenges to ascertain an accurate baseline, especially for small FSPs and aggregators, is a barrier and therefore baseline principles should be defined which must be accepted in any market (33,40,47). The Swedish demonstrator also adds that a larger sample for the baseline is necessary, as only having a baseline when having a bid on the market is not good enough to be able to avoid gaming (33).

In this context, different baseline methodologies have been proposed and implemented, allowing for the verification of service provision from non-scheduled FSPs. The authors in (122) and (123) describe the various types of baselines for demand response available at their time of writing and the desirable properties for a baseline method, namely (i) accuracy, (ii) integrity, (iii) simplicity and (iv) alignment. In addition, CoordiNet deliverable 2.1 adds the dimensions of (i) the trading agent, (ii) type of unit, (iii) market/product timing, and (iv) market model, as key to consider when choosing the best suited baseline methodology (28). *To reduce complexity for FSPs, as well as enforce anti-gaming measures, best practise of baseline methodologies according to type of FSPs should be implemented. As stated, baseline methodologies should be checked already in the prequalification. This will also reduce the need for implementing penalties as an accurate baseline will reduce the risk of non-delivery (Action-Recommendation 4.4).* The need for EU-level harmonisation with regard to baseline methodologies was also emphasised in Europex's position paper on harmonised implementation of the CEP (71). The CoordiNet partners, evaluated and compiled a set of possible baseline methodologies and summarised pros and cons for each, based on the work done in deliverable D2.1, which can be seen in Table 19 (28).

Table 19. Baselines methods and their advantages and disadvantages. Sourced from CoordiNet deliverable 2.1.

Baseline	Advantage	Disadvantages
X of Y (and variations)	• Easy to compute • Easy to understand and communicate • May incentivise flexibility provision (depending on choices of parameters)	• Risk of gaming (small, depending on design choices) • Load-oriented. It could be used for other types of DER with adjustments. Accuracy may be lower.
Regression	• High accuracy • Low gaming potential	• Complex to compute (curve fitting) and understand • A large amount of past data required
Comparable day	• Easy to compute • Easy to understand and communicate	• Subjective day selection • Ex-post calculation. It is not possible to verify in real-time • Need to differentiate between labour, national holidays and weekends

Baseline	Advantage	Disadvantages
Rolling Average	• Easy to compute • Easy to understand and communicate	• Accuracy is good for stable loads. DERs with sudden variations over days or weeks will face accuracy problems
Capacity Service Limitation	• Overcomes several issues with baseline definition (accuracy, gamming, simplicity)	• It is not limited to a baseline method but requires a product and market design definition. May lead to a complex market design and integration with other energy/capacity markets.
Meter before/meter after	• Easy to compute • Easy to understand and communicate • No past data is required. No previous calculation	• Static baseline: not suitable for long periods of activation • Highly prone to gaming. Mostly suitable for very fast products (e.g., FCR, aFRR)
Nomination-type baseline	• An alternative for DER types when other methods are not suitable	• Possibly not suitable for small DERs • Additional conditions are needed to avoid gaming and provide incentives for the submission of accurate baselines

CoordiNet deliverable D2.1 also provides an in-depth assessment considering the different characteristics that can guide the choice of baseline methodology (e.g., types of DER technologies, FSPs, products, services, and TSO-DSO coordination) and provides detailed description of recommendations for baseline application within the three demonstrations. The report concludes that "one size fits all" is difficult and perhaps not desirable to achieve and a decision tree, see **¡Error! No se encuentra el origen de la referencia.** Figure 17, to help guide the choice of baseline methodology (28).

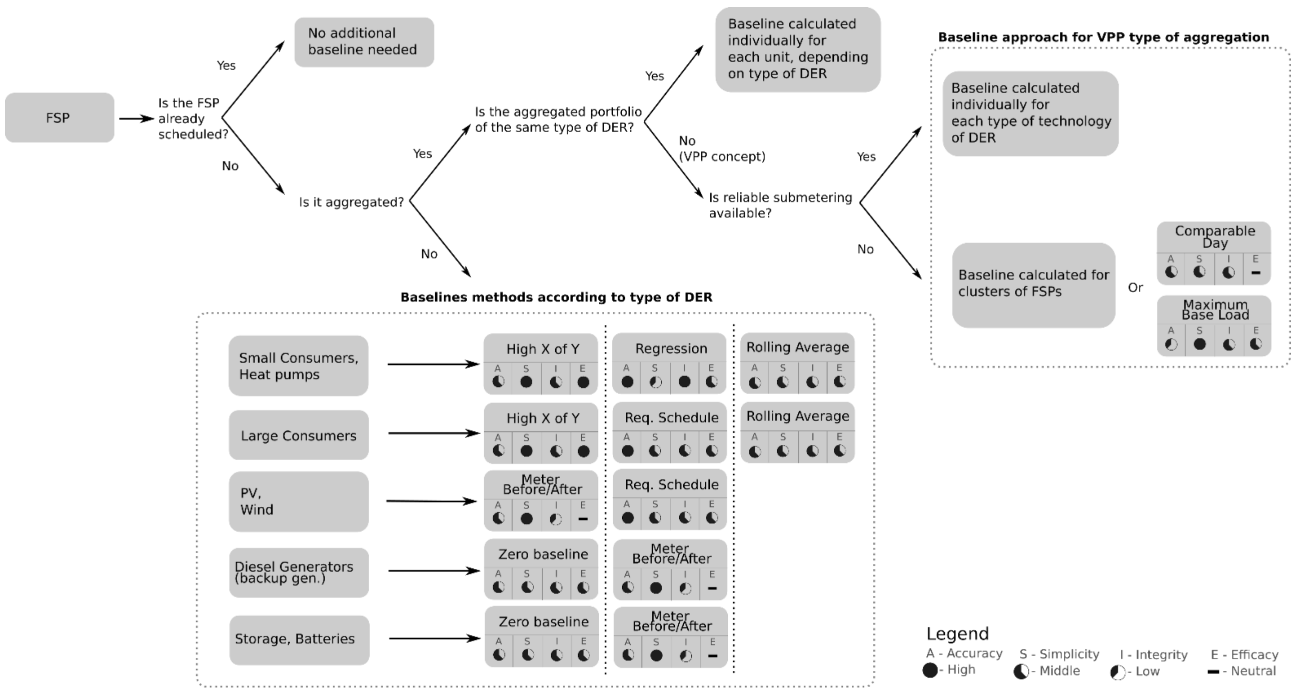


Figure 17. Baseline decision tree. Sourced from CoordiNet deliverable D2.1 (28).

When defining the baseline methodology the relevant motivations of concerned actors (FSPs, market operator, SOs, etc.) should be taken into consideration. The chosen method, as well as the settlement/remuneration based on this, needs to be agreed with and transparent towards FSPs. The regulatory framework should therefore enforce the transparency of baseline assumptions. Also, system operators/market operator should build bilateral agreements (contracts) that ensure the validity of the chosen method and its economic consequence for the FSP.

Post-delivery different verification methods can be used to establish whether the product has been delivered by the FSP. Some verification methods can be programmed and automatically applied (like alteration of production plan upon clearing of bid) while others will be less exact (statistically significant deviation from forecasted or typical aggregated domestic load). Yet others may not be suitable for automatic evaluation at all and require manual spot-check inspections and acceptance sampling. More work is needed in regard to this topic and potential rebound effects must also be further analysed in the domain of accurate settlement processes where still little is known. For example, consider that an FSP reduces their consumption of energy of their specific DER but simultaneously has the need to use another energy consuming appliance or function. Strictly speaking the FSP has adjusted their consumption of the market dedicated DER but this reduction might not be visible in their overall load profile due to the unexpected need to use another appliance. However, from a system perspective, without the reduced consumption of the committed DER the consumers load profile would be even higher. How to manage this in relation to the choice of baseline methodology and the verification process deserves further investigation.

In addition, baseline provision of small-scale DER is further complicated by the previously mentioned issue that the DERs primary function might be to satisfy consumers' requirements that are variable and not perfectly predictable and accurate forecasts to support a baseline provision will be challenging.

4.4.4.2. Accurate measurement data and data access

Depending on the flexibility product to be delivered, each flexibility provider should submit the corresponding data with minimum granularity and frequency and coordinated with the flexibility service attributes. The joint report by ENTSO-E and all European Associations representing DSOs provides a review on the telemetry requirements for measurement, validation, and settlement purposes for flexibility services (56). At European level, some general provisions state that technical capabilities are necessary to comply with the telemetry requirements of each product. The telemetry requirements are part of the product design and the prequalification processes. Such requirements would allow certain level of standardisation as discussed above in chapter 4.3.

One of the points highlighted is that the telemetry requirements should not impose additional barriers for the participation of any flexibility provider in the flexibility markets (56). The European legislation encompasses a wide set of data to be exchanged to ensure certain level of harmonisation, but the national authorities are the responsible entities to ultimately define the data exchange requirements. European Regulation 2017/1485 specifies the requirements of data exchange for existing or new facilities above certain size or for facilities providing system services (112). The data exchange requirements for small units (in general, those ones below 1 MW) shall be determined at national level through for example the national grid code or another national legislation (56). It is worth mentioning that in the case of aggregation, lack of measurement data transparency can result in gaming as it becomes difficult to verify the delivery of procured flexibility from a specific market participant. As mentioned in Theme 3, it should also be determined which data can be provided in an aggregated form and which data cannot to secure a correct settlement.

As already presented, roll-out of smart meters will be crucial for the functioning of these markets. In the settlement process, one of the main barriers for reaching the telemetry requirement, and for the deployment of real-time markets can be the lack of technical means (such as smart-metering, hourly or quarter-hourly measurement, or real-time monitoring). Likewise, Villar et. al. finds that one of the barriers for the deployment of local markets at distribution level is the lack of metering devices for reliable real-time measurements (96). Low observability in LV grids due to lack of metering data will make accurate settlement processes difficult to achieve. In countries or regions where the deployment of smart meters is delayed, rules in Member States must be in place that specify the conditions for the usage of sub-meters (12).

The roll-out of smart meters is perceived as the most important step for the achievement of reliable measurement and thereby settlement, which requires including both investment plans for installations by the SOs, as well as regulatory incentives to support this smart meter rollout. Alternatives to smart meters appear in several of the analysed references, as also many DERs connected to the LV grid have their own meters (76,86,96). If own meters should be allowed it should be made sure that these smart meters have enough accuracy to measure the activated flexibility, and measurements should be controlled and validated by an independent actor. The metering data should also be accessible to the DSO for real-time analysis and flow forecasts, especially in cases where meters are not handled by the DSO. GDPR issues occurring when using meters in households that are not owned by the DSO is also raised as a possible barrier and solutions should be developed to help DSOs to navigate this and ensure compliance with the regulation (33,40,47).

4.4.5. Theme 4 Recommendations

Table 20. Theme 4 recommendations and list of actions derived from the CoordiNet demonstrations and analyses.

Recommendations	Actions	Level of implementation	Priority
Timing aspects and integration of new flexibility markets			
4.1 The CoordiNet project does not recommend standardising market timing on EU level as it depends on national and local context. However, effort should be put on integrating flexibility markets with already established markets and some high-level principles can be recommended.	To enable FSPs to participate and stack value over several markets, overlapping clearing times should be avoided as this can have a negative impact.	National	High
	The SOs should arrange local congestion management and voltage control markets taking into account the timing of already established balancing markets to not disrupt the security of the system.	EU & National	High
Prequalification			
4.2 Harmonisation of requirements and processes for prequalification is desired across flexibility services and market platforms to increase liquidity.	Prequalification requirements for flexibility services at distribution level should be fully included in the upcoming Network Codes.	EU	High
	Requirements in the product prequalification process for market participation should not be too strict but should be set with a broad set of FSPs in mind. Such requirements should however include conditions regarding reliable real-time measurements and provision of baselines to prevent gaming.	EU	High
	To reduce the risk of excluding FSPs from markets, certain requirements could be checked ex-ante activation as a part of system	National	Medium

	prequalification of minimum necessary requirements.		
	Product requirements could be checked in connection to the real activations, to ex-post validate that the unit is able to provide the specific product needed. If the validation is positive, the prequalification can automatically be renewed.	National	Medium
	Processes should be automatised to the largest extent possible. In addition, prequalifying for a service with more strict requirements could entail automatic qualification for services with less strict requirements.	EU & National	High
Procurement and activation			
4.3 Inclusion of network simplified representation in the market clearing is recommended to ensure that network limitations are not violated and enable both TSO and DSO to select the bid that most efficiently solves the issue at hand.	Responsibility for bid selection by using a merit order list should remain with SOs as the responsible agents for grid management. This should be defined in a transparent way to ensure trust in pricing and market operation.	EU & National	High
	The inclusion of network representation has to be done while keeping the complexity of the clearing algorithm down, thereby keeping computational complexity low and ensuring fast clearing times but while adequately ensuring the security of the network operation of all the grids involved.	National	High
	An impact assessment is needed of methods to include network representation in the market clearing to ensure sufficient description of the grid.	National	Medium
Settlement			
4.4 Harmonisation of settlement processes in European flexibility markets should be strived for.	To reduce complexity for FSPs, as well as enforce anti-gaming measures, best practises of baseline methodologies according to type of FSPs should be implemented. As stated, baseline methodologies should be checked already in the prequalification. This will also reduce the need for implementing penalities as an accurate baseline will reduce the risk of non-delivery.	EU	High
	Verification of delivered flexibility requires a transparent settlement process. In some cases, this might call for an independent third-party performing this process, which could be subject to external auditing.	EU	Medium
	Harmonisation of settlement processes is contingent on realisation of actions described for data and information sharing/product specifications regarding telemetry requirements.	EU	High

* Business
Techno-economic
Institutional and regulatory
"Social"

4.5. Theme 5: Enabling FSP contributions to innovative market solutions

The challenge: In this chapter we look closer at two developments within system service provision that are still in a very early state of testing, flexible system services for reactive power and by use of P2P markets. These solutions are still immature concepts and could not be included in the CoordiNet project at the same level of detail as the other more developed BUC.

Key take-aways from the CoordiNet experience:

Markets and products for reactive power

Reactive power can neither be transported over long electric distances nor across several voltage levels. Therefore, reactive power must be provided by local assets on an appropriate voltage level. The farther away the asset lies within the system, the less effective. The organisation of any large-scale market is therefore unfeasible. In addition, as reactive power in many Member States is provided by mandatory connections and by SO owned equipment, it is not as straight forward to implement a market solution as it is for congestion management for example.

These innate characteristics result in barriers for a strict market-based approach of procurement and should therefore be enabled to co-exist with a rules-based approach. The efficiency of both approaches will vary depending on the context and thus need to ensure the ability of SOs to choose the most efficient solution in each case. It is therefore recommended to implement regulatory sandboxes where this system service and the favourable conditions for its adaptation within a market-based approach to flexible system service provision can be further explored.

Peer-2-peer markets for system services

P2P trading is the buying and selling of energy between two or more grid-connected parties and this concept has emerged as an alternative for prosumers to actively participate in the energy market. However, few projects focus on the establishment of P2P markets for explicit system services delivery on the request of the DSO/TSO which has been the focus of the CoordiNet project. The CoordiNet demonstration focused on large-scale actors and trading was implemented at fixed and planned periods where curtailment of renewable energy sources, in this case wind, would otherwise be necessary instead of in a continuous market with many small-scale actors. The demonstrations showed great potential in allowing for more efficient use of already existing grid infrastructure as well as avoidance of renewable energy curtailment. The scale of the test was however not sufficient to draw any strong conclusions.

As with market-based solutions for reactive power, CoordiNet recommends the creation of regulatory sandboxes to assess the benefits and impacts of P2P seeing as these are still largely unknown. The potential for incentivisation mechanisms for market establishment should also be further explored to discern whether or not investment in market implementation and participation can be retrieved through the economic benefits of P2P for system services.

As already described, reactive power products and P2P markets could not be included in the CoordiNet demonstrations at the same level of detail as active power and traditional energy market concepts since they are in an early development phase. Thus, potential recommendations valid for flexibility market concepts that have developed further will be less applicable for these two trials. In the following we will therefore discuss the findings from reactive power and P2P demonstrations in isolation to give recommendations adapted to the readiness level of these concepts.

4.5.1. Markets and products for reactive power

To keep voltage within operational limits, system operators regulate the injection and absorption of reactive power. Reactive power has the unit of volt-ampere reactive (VAr) and needs to be balanced to be able to transfer active power across the HV and MV grid. However, the movement of reactive energy consumes transmission resources, limiting the ability to move active (real) power and results in power losses (124). Therefore, sufficient generation capacity of reactive power must be available and strategically located to a) maintain it within safe operational conditions and, b) stabilise voltage - after an incident. Due to the interdependence between active and reactive power, voltage control could be split into the same set of products found in frequency control (124). Reactive power has, as mentioned, a profound effect on the security and health of the system and in this chapter, a closer look will be taken into the potential for reactive power services on flexibility markets. However, due to the function of reactive power, where power flows in both directions between source and load, it is problematic to separate it from the effect on active power provision.

Traditionally, voltage support is provided through reactive power compensation by large power plants equipped with synchronous generators connected to the transmission system to supply the power system (125). Most commonly the SO owns the power lines and connected equipements, meaning that investments and operational costs are returned to the SO as revenues collected by charges applied to the served customers (126). Although voltage control services are already provided, they are mainly as a mandatory requirement. Thus, even if technologically mature, the engagement of third parties in market-based procurement for this service still lacks acknowledged frameworks for procurement mechanisms, which are needed to promote the required investments, achieve market liquidity, and foster competition (125).

The transmission grid will need reactive power voltage control in a nonlinear manner. In instances of low loads, the system itself generates reactive power that must be absorbed. On the other hand, the system consumes large amounts of reactive power at heavy loads that must be replaced by injecting reactive power. In a liberalised electricity sector, these resources are third-party owned; however, voltage support is, to some extent, mandatory; additional voluntary service is envisioned in some cases (125,127,128). Payments are typically based on bilateral agreements or regulated tariffs (125,127–129). In a decentralised, liberalised, and fragmented power system, traditional voltage control practices are no longer fully applicable. The reduced availability of large power plants and the increasing volume of DERs undermine the traditional control practices (130–132). Moreover, in RES, the reactive power capacity can depend on the active power production (depending on the technology considered), which clearly constrains the provision of this service by these types of generators. If the instantaneous need for active power increases, the wind farm must produce adequate reactive power. Since the amount of active power depends on the wind force, it can be concluded that the reactive power also depends on the wind, making production more uncertain (133). Further investigation on these interlinkages is needed and the effect on the product and market design needs to be considered. This was not in scope of the CoordiNet demonstrators, which mainly focused on the technical aspects of reactive power delivery.

Distributed resources should be involved in a decentralised voltage control to solve local grid problems. However, in the EU, third parties' participation in the voltage support is still in its early stage. Even if mature from the technical perspective, the engagement of third parties in voltage control still lacks in acknowledged frameworks for products and procurement mechanisms, which are needed to promote the required investments, achieve market liquidity, and foster competition (125). *Due to the immaturity of this service, CoordiNet cannot provide strong recommendations for implementation and regulatory sandboxes should be implemented to allow for additional tests at higher scale. Overall, there are however, some key aspects to take into consideration as the use of this market develops. (Recommendation 5.1).*

4.5.1.1. Technical characteristics

The technical characteristics of voltage control and reactive power support require the adoption of dedicated procurement mechanisms; the related complexity makes it not feasible to straightforwardly extend the market mechanisms and the products used for balancing or congestion management.

Voltage control is considered a local need due to its technical aspects (134). Moreover, voltage control can be obtained with active and reactive power actions, depending on the voltage level of the grid. The impact of the active and reactive power flows on bus voltages depends on the characteristics of the grid. Typically in transmission systems, bus voltage magnitudes are mainly influenced by reactive power flows; the influence of active power flow is neglected (135,136). Conversely, in distribution systems, the influence of active power flows is not negligible (136,137). Moreover, grid topology is relevant since voltage control strategies change between meshed and radial grids. In meshed grids the number of busses that can effectively contribute to clear a voltage issue may be higher than in radial grids, determining a higher efficiency of the corresponding market-based procurement (37). Given these conditions this product could never really be considered as homogeneous. Definition of common attributes that product specifications must contain is however advisable containing aspect such as product quantity, product timing, procurement frequency, activation aspects, and locational information of the product.

Besides that the characteristics of the grid require different voltage control approaches, products, and procurement mechanisms, the network itself (i.e., lines and components) requires or provides reactive power compensation depending on the specific operating point. The operating point of the grid influences the market area and may require continually updating relevant parameters such as voltage sensitivities. *Since voltage sensitivities depend on grid topology and system state, they should be updated dynamically and continuously to procure the required flexibility. This requires good network monitoring and system state estimation. If this is not possible, voltage sensitivities can be calculated approximately based on grid parameters, using the resistance and reactance of the lines. Even in this case network topology is necessary and therefore voltage sensitivities should be updated when network reconfiguration is applied. (Action - Recommendation 5.1).*

In addition, due to influence on voltage, transmission losses, and network loading reactive power can neither be transported over long electric distances nor across several voltage levels. Therefore, reactive power must be provided by local assets on an appropriate voltage level. The further away the asset lies within the system, the less effective. The impact that reactive power adjustments have depends highly on the R/X ratio of the lines. The R/X ratio is the amount of resistance R divided by the amount of reactance X, which also happens to be the tangent of an angle created by reactance and resistance in a circuit. In MV grids, the R/X ratio is usually around 1, so active and reactive power have equal impact on the voltage rise (138). This might result in very local market sizes in the higher voltage grids due to their higher R/X coefficient.

Because of the reactive power technical characteristics, it is often perceived as a topic for national level regulations and frameworks and not at EU-level due to the impacts of local and contextual specificities (29). In general, local market mechanisms for DSOs can have too low liquidity for really being competitive, and no mature proposals seem to exist yet (78). Furthermore, the characteristics of reactive power demand and the network voltage limits may lead to high price volatility of reactive power spot pricing (139–141).

4.5.1.2. Procurement and remuneration alternatives

EC Directive 944/2018 (142) establishes the regulatory framework for electricity generation, transmission, distribution, supply, and storage. Article 31 paragraph 7, Article 32 paragraph 1, and Article 40 paragraph 4 set that TSOs and DSOs shall use transparent, non-discriminatory, and market-based procedures to procure non-frequency ancillary services for voltage control. Market-based procedures have to be preferred unless the regulatory authorities grant derogation if the procurement of such services is not economically efficient or would lead to severe market distortions or higher congestion (142). Considering voltage control, the mechanism to procure the related non-frequency services is discussed (29).

According to CEER (29), four general types of flexibility mechanisms for procurement can be found:

i. Rule-based: Mandatory requirements set by regulation.
ii. Network Tariffs: incorporating flexibility incentives (Time-of-Use, dynamic charges, etc.).
iii. Connection Agreements: DSOs reach an agreement with new grid users who provide flexibility in exchange for some sort of compensation (e.g., lower connection charges).
iv. Market-Based Procurement: DSOs explicitly procure flexibility from local markets.

In compliance with Directive 944/2018, market-based approaches should be privileged, while a rule-based approach should be limited to specific and exceptional situations and specific regulations at a national level where the market is not efficient. This could for instance be for reactive power regulation depending on local measurements where few potential providers are available (29). Also, aspects such as long procurement cycles, lack of supply, and regulatory support for SO ownership instead of service procurement may lead to a continued preference of bilateral agreements over a marketplace for voltage control (99).

The remuneration for transmission generators is based on procedures established by regulators that consider reference costs or by long-term bilateral contracts; where capacity, activation, or both are remunerated. Some frameworks also recognise the lost opportunity related to the active power output (125,127–129,143,144). What should be considered is that rule-based provision is sometimes not remunerated; simply legally required, and if to stay with only rule-based approaches, FSPs will stick to the bare minimum legal requirement even if they have the potential to provide more support (especially if not remunerated). *The coexistence of rule-based and market-based provision of voltage/reactive control services should be enabled to ensure the ability of SOs to choose the most efficient solution in each case. (Action - Recommendation 5.1).* The strongly local character of this service is essentially what will drive when/where rule-based or market-based services are the most efficient option. The inclusion of additional service providers and the rules for their proper remuneration also opens the question of remunerations to users already providing voltage support (99). However, a procurement framework that combines different types of procurement mechanisms can be effective in the case of voltage control to guarantee a minimum level of support and encourage the availability of additional voltage support capability (29,125,145).

The SRA made within D6.4 (146) looked into DER provision of voltage control for TSOs and found evidence of this in the analysed countries' regulations. Table 21 shows the remuneration schemes used in the 3 demo countries as well as five additional member states included in the analysis.

Table 21. Assessment table for TSO's Voltage Control Mechanisms and DER participation from the SRA in CoordiNet deliverable 6.4. In general terms, a rating of 5 means that the status in the specific country is completely compatible to what is needed for the replication of the CoordiNet's BUCs. Source from CoordiNet deliverable 6.4.

Q5	Is voltage control a market-based service?		
Q6	Can DER provide voltage control?		
	Q5	*Q6*	*Short rationale*
Greece	1	0	Voltage control is mandatory. No DER participation. No settlement mentioned.
Spain	1	0	Voltage control is mandatory. No DER participation. No settlement mentioned.
Sweden	1	0	Voltage control is mandatory. No DER participation. No remuneration to providers.
Austria	2	0	Voltage control is mandatory. No DER participation. Marginal pricing used (remuneration in place).
Belgium	4	0	Voltage control is a market-based service. No DER participation. Remuneration in place.
Germany	1	2	Voltage control is mandatory. RES and storage can provide voltage control. No settlement mentioned.
Italy	1	0	Voltage control is mandatory. No DER participation. No settlement mentioned.
The Netherlands	3	1	Voltage control is a "hybrid" service. RES can provide voltage control. Pay-as-bid used (remuneration in place).

Moreover, clear requirements for bilateral contracts need to be defined to guide the negotiation among the parties (29). The simultaneous use of flexibility mechanisms is not excluded by CEER (29). Codes and rules for flexibility requirements, network tariffs, connection agreements and rules for market-based procurement should be defined at national level (29). However, *before deciding on a market framework for reactive power products, several market mechanisms need to be explored and evaluated further considering entry costs, price volatility, maturity of the mechanisms, among other relevant criteria. (Action - Recommendation 5.1).* One thing that should be taken into consideration when developing market solutions for flexibility services overall is that *principles for product prequalification and communication protocols, developed for flexibility services (see action for recommendation 3.5 and 4.2 in theme 3 and 4), should take into consideration the qualities of reactive power services. (Action - Recommendation 5.1).*

4.5.1.3. Market solutions tested in CoordiNet

In the CoordiNet project, power products have been tested in the Greek and Spanish demonstrator in the BUCs, GR-1a, GR-1b, ES-3 as a part of the voltage control service.

In the GR-1a and GR-1b, voltage control has been tested at two sites. Additional to this, the SRA analysis presented in the deliverable D6.4, where three selected cases allowed to investigate the impact of the number and location of the FSPs on the performance of voltage control and the related market procurement (37). The network scenarios studied for the Greek demo highlight the impossibility of solving all voltage violations exploiting only reactive power. The increased penetration of RES leading to an increased availability of reactive power capacity due to the power electronic converter relieves the problem allowing solving a higher share of voltage violations; however, the effectiveness of reactive power support is limited. The oversizing of the power electronic converters of inverter-based RES to increase the reactive power capacity available for reactive power support do not achieve a comfortable level of performances in terms of avoided voltage violations in reference to the scenario of increased RES size (i.e., the scenario in which not only the converter size is doubled but also the active power generated) (37).

In the ES-3 voltage demo performed, both the functioning of the voltage market mechanism and the management of the voltage had been successfully tested. The DSO was able to submit the relevant information on the reactive power needs to the CoordiNet Common Platform. The FSP PESUR, a 42MW, onshore wind farm in Andalusia, was through their market agent able to send the corresponding reactive power bids. Then, the voltage market cleared correctly (87). Concerning the network operation, the DSO has been able to avoid voltage deviations using the reactive power regulation capabilities of the PESUR FSP connected at the distribution level. The DSO has been able to control the FSP PESUR by sending voltage and reactive power setpoints through the CoordiNet Common Platform. This demo also proposes a new zonal market design intended to encourage providers to offer their whole available capacity in addition to the mandatory one, as indicated in the RfG NC. Since voltage control is local, each network manager must define zones of electrical influence and establish an additional reactive capacity requirement per zone. The procurement of additional capacity to the mandatory requirements for generation units to manage voltage control is a new service which has not been remunerated separately from the congestion management market. Although an initial market design proposal has been established, the functioning of that market mechanism is still to be tested in the system (87). The tests in the Spanish demonstration also showed some technical barriers where some participating generators could not be retrofitted to enable third-party-resources to implement a scheduled profile or automatic control of the resources' behaviour (87). Such automation would be required to be able to address steady-state and dynamic voltage control (99). For other resources participating such investment in already available technology could enable the needed upgrade in control and information and communications technology (ICT) systems to be able to deliver voltage control. Likewise, the absence of a defined protocol for communication, between the market participants of setpoint for voltage control creates uncertainties for the third-party resource on how to run their assets.

From the SRA results of the Spanish case study, it can be concluded that for some scenarios, the availability of FSPs better located in the network to the voltage issues is crucial for solving the voltage problems, providing evidence of the strict locational characteristic of voltage control. Hence, sufficiently high participation of potential FSPs is fundamental to avoid market distortions and achieve efficient procurement mechanisms. To avoid gaming behaviour when there is low liquidity in the market, long-term products can be used. The SO by then have time to go for an alternative in terms of grid reinforcements or additional equipment if the prices of the bids on the markets are set too high by the FSPs. For short-term products, market power might be an issue as the SO then does not have any alternatives than to procure the bids available on the market, even at extensive prices. An issue with long-term products can be over-procurement by the SO to be sure that there is enough capacity to cover the need.

General conclusion from the SRA analysis done for the two demonstrators showed that the augmented availability of FSPs in terms of size and location is beneficial for increasing the effectiveness of the market-based procurement of voltage support. Increasing the probability of having FSPs electrically close to the voltage issue is crucial for control effectiveness. An increased FSP size, and then, an increased reactive power support capacity, is beneficial for voltage control if the considered FSP is well located with respect to the voltage issue (37).

The Greek demonstration highlights that reactive power products are required for voltage control, but currently few resources can offer this type of product in the distribution network (147). Conclusions from the demonstrations have identified the high investment in necessary equipment as a barrier for the units participating (47). The tests in the Spanish demonstration showed the technical efficiency of the solutions tested. However, barriers for certain types of providers, such as RES units, may still exist. Some of them might require retrofitting, which could represent an entry barrier to voltage control markets (87). *As the monetary threshold for new market participants to provide this service is quite high, and the maturity of this service is low, the return on investment is uncertain. Focus for development should therefore be on R&D pilots primarily (Action - Recommendation 5.1).* The Spanish demonstrator highlights that future research should also analyse the effect of economic incentives, penalties or incomes, for reactive power to guarantee that the new scheme provides efficient incentives and a level playing field for demand-side resources. Also, for the still unknown aspects of these markets (e.g., entry barriers for the different technologies), pilot projects and sandboxes could be used to further inform regulation on the actual best implementations of voltage control markets (87).

4.5.2. Peer-to-peer markets for flexibility service provision

P2P markets are not a new concept, but for the application of buying and selling system services, it has just recently been brought up as a solution and is mainly tested within R&D initiatives. According to the EC's Renewable Energy Directive "'peer-to-peer trading' of renewable energy means the sale of renewable energy between market participants by means of a contract with pre-determined conditions governing the automated execution and settlement of the transaction, either directly between market participants or indirectly through a certified third-party market participant, such as an aggregator" (148). Meaning that P2P trading is the buying and selling of energy between two or more grid-connected parties. This would allow consumers the choice to decide from whom they purchase electricity, and to whom they sell it via a secure means of information exchange. P2P trading has thus emerged as an alternative for prosumers to participate in the energy market actively. Also, P2P energy trading provides increased flexibility to end-users, provides opportunities to consume clean energy, and supports the transition to a low-carbon energy system.

However, few projects focus on the establishment of P2P markets for explicit system services delivery on the request of the DSO/TSO which has been the focus of the CoordiNet project. Most previous projects and demonstrations have rather taken the approach to test P2P markets for energy trading, focusing on grid constraints to avoid causing negative impacts on the grid. Therefore, no proper operational framework, ways for peers to offer their flexibility to DSOs and TSOs, or incentivization mechanism for system service provision by peers are sufficiently explored or defined.

4.5.2.1. Peer-to-peer concept in CoordiNet

In the Swedish demonstration, BUC SE-1b, the P2P concept was tested at two sites, the Västernorrland and Jämtland, as well as on Gotland, with the purpose of reducing the need for curtailment of renewable power production in times of grid maintenance. As previously described, in Sweden **regional** DSOs operate electrical networks (normally between 70 kV-130 kV), in between the TSO's 400 and 220 kV lines and **local** DSOs. The regional DSO has a subscription towards the TSO that sets the annual level of power that can be drawn from the TSO grid to the regional grid. This subscription limit is not the physical constraint of the grid which is higher than the subscription limit. Given this set-up, in the case of maintenance or different grid situations, the subscription level of regional networks may be reduced to uphold the security margins of the TSO. A P2P trading platform was therefore developed with the ability for the DSO to introduce grid bottlenecks to create a market where affected power consumers and producers can trade capacity between themselves.

In the Västernorrland and Jämtland region the P2P market was set up to avoid curtailment of renewable energy production, wind and hydropower, due to planned maintenance on the TSO lines. The grid maintenance in the demonstration sites typically occur for a couple of days, once or twice per year. Currently, there is no reimbursement for production loss for the units affected by the maintenance. A P2P market could be a way for the producers to increase their allowed output capacity during the maintenance and thereby reduce their financial loss (see Figure 18). For example, during low wind periods wind power producers in Västernorrland and Jämtland would be able to sell their unused capacity to make an extra income. The buyer could be a hydro producer that can increase production above its temporary constrained subscription level. The actors on the P2P market were only the energy producers and the commodity that actors trade on the market was set as "grid space", i.e., excess capacity. However, due to cancellation of planned maintenance, testing could not be carried out during the project period and instead a simulation was performed. Despite this, the simulation did successfully prove the feasibility of the platform, market, and concept.

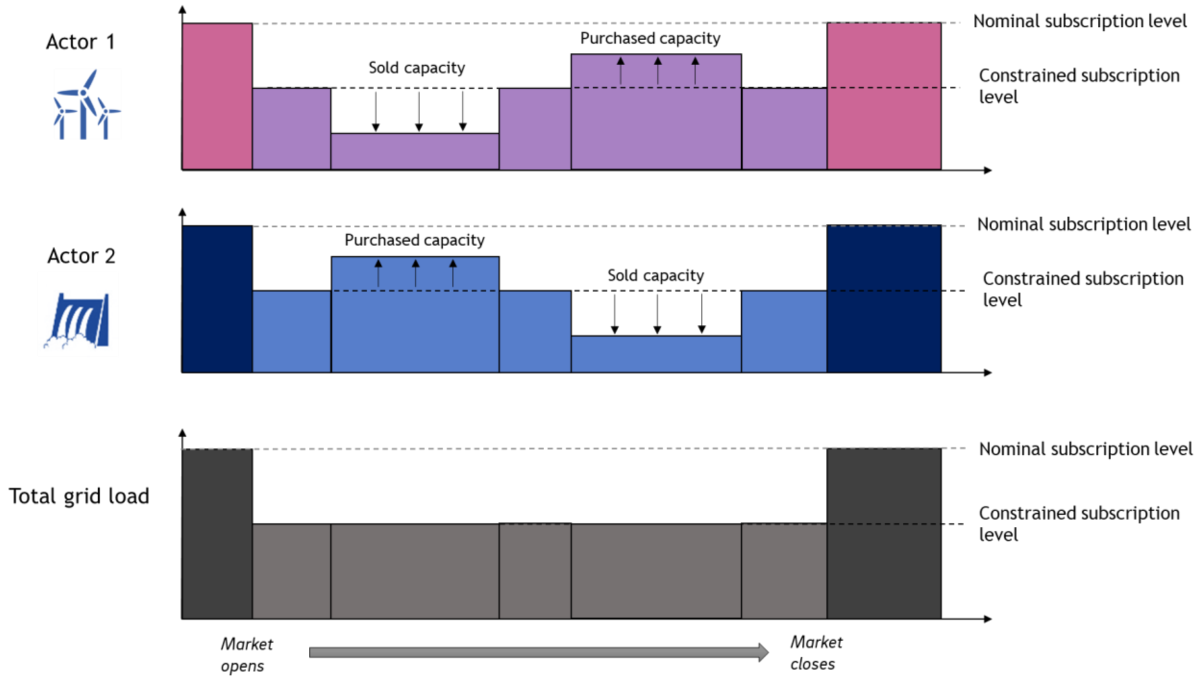


Figure 18. Illustration of two flexibility providers acting on a Västernorrland and Jämtland P2P market during a temporary constraint, showing capacity trading and the relation to subscription levels. Sourced from CoordiNet deliverable D4.7.1 (65).

On Gotland the purpose of P2P trading was to increase wind power production during curtailment periods allowing peers to initiate load increase to absorb the additional wind power production (see Figure 19). Although curtailment of wind production may occur during the entire year it is during maintenance, HVDC links revision, that curtailment is most likely to occur. The P2P actors were the Gotland wind producer's association and the local district heating unit. In Gotland two periods of one week each was identified. The first week led to one cleared and accepted bid for one hour of a total of 4 MW. The second test week, energy prices were too high, and no bids were cleared.

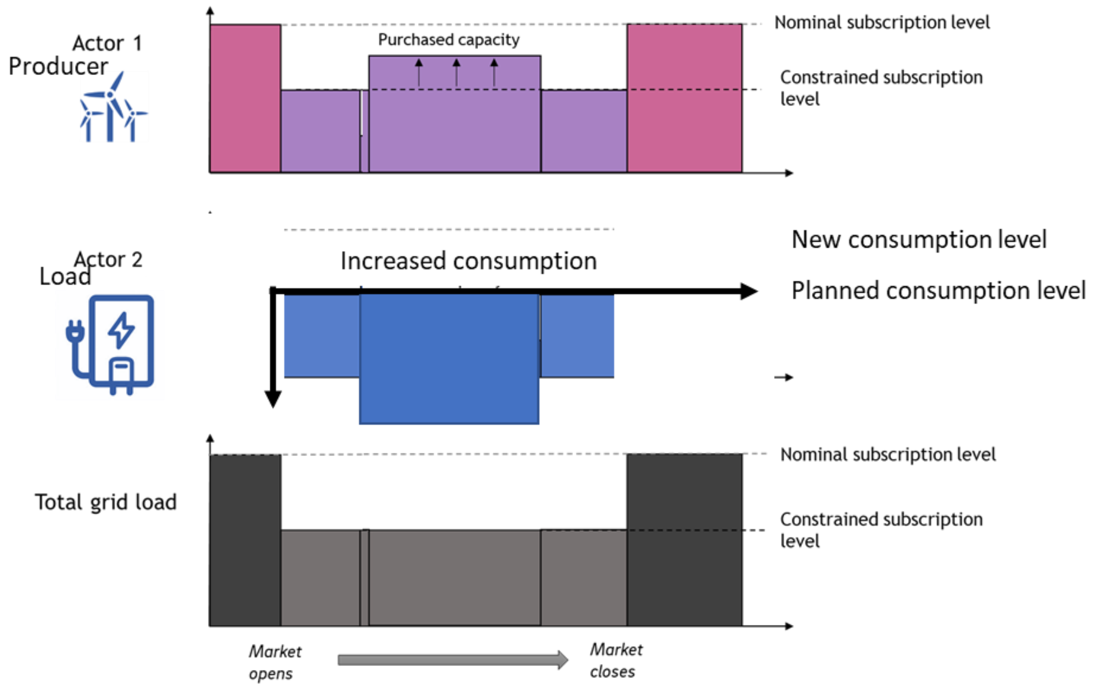


Figure 19. Illustration of two flexibility providers acting on Gotland P2P market during a temporary constraint, showing increased consumption to equal non-executed DSO curtailment command, and the relation to subscription levels. Sourced from CoordiNet deliverable D4.7.1 (65).

In this concept the DSO would host the market platform, provide information on curtailment periods, and monitor the transactions to ensure the obligation for reduced power flow is met by load producers, but is not a part of the trading process (149). In the P2P market platform, blockchain was developed for both tamperproof recording of transactions and contracts between the peers, as well as validation of contract fulfilment. These blockchain applications could not be tested to its fullest given that the validation process requires actual measurements from the trading assets which in both the case of Västernorrland and Jämtland, and Gotland could not be delivered. Even so, the results from the tests show that the utilisation as such was successful. The need for block-chain applications will most likely rise when there is high market liquidity with several different assets and companies that trade with each other. Other examples of P2P market pilots can be seen in Infobox B. The main difference between CoordiNet and other pilots is that the market platform in CoordiNet is managed by the DSO and not an independent market actor. In addition, the purpose of the pilot is exclusively to avoid production curtailment due to planned maintenance. Other pilots have looked at a more traditional flexibility service setup where smaller local actors provide flexibility to the DSO together with a more traditional set up of P2P where several small-scale actors come together to trade energy services in a continuous market. The CoordiNet demonstration focused on large-scale actors and at fixed and planned periods where curtailment would otherwise be necessary. For the purposes of this discussion, it is therefore not advisable to extrapolate findings by comparison between these pilots to provide general recommendations for P2P markets for flexibility system service provision. In the following we will however highlight some main findings from the CoordiNet P2P market.

Infobox B. Brief overview of other peer-to-peer system service market pilots.

Piclo Flex	Interrface
Another example of a project explicitly testing P2P markets for system serives is the UK based Piclo Flex **(150)**. In this project an auction-based P2P local matching platform was implemented which focuses on providing flexibility services to the DSO. Piclo Flex provides an independent platform to publish flexibility needs based on the demand location where the DSOs can identify qualifying assets in the constraint management zones, enabling them to source flexibility with precise locational, technical, and temporal requirements. The project is considered a P2P market platform as matching of peers is conducted. However, the request of the service and its procurement is still the central focus.	In the Interrface project (151), a different approach to P2P market is tested for small customers, who are not capable of participating at existing (wholesale) electricity markets. In their concept, consumers have the choice to buy directly from their neighbours, from specified generation units motivated by for example their social or ecological impact, or simply due to economic reasons. Simultaneously, this local market supports DSO operation as the market algorithm considers the effects of potential trades on grid constraints and block trades that would cause congestion. In addition, a dynamic grid usage tariff is proposed that favours trades (with price incentives) that reduce negative effects in the grids. Therefore, in this specific case, congestion management is not based on a direct activation by a system operator, but part of the proposed P2P market design.

4.5.2.1.1. Demonstration specific limitations

The CoordiNet demonstrations of P2P markets gave proof of concept of these specific market trials and developed tools. What the set-up of this demonstration showed is that due to the nature of this concept, where the market would only operate during a short period of time spread across the year, it became time consuming for staff at production units and the market operator to arrange (and potentially modify) the market setup. Seeing that it is not possible to influence scheduling, re-scheduling or even cancellation of planned maintenance, staff would need to spend time to keep up-to-date with developments. The time spent to set up and monitor potential market opportunities compared to the potential increase in power output that the P2P market would allow for would seldom suffice to attract more participants as the business case is not strong enough.

Another limitation to large scale implementation in Sweden, highlighted by the Gotland demonstrator, was related to Swedish national taxation and grid fees. While the merits may seem straightforward to avoid wind curtailment by increasing heat production at district heat plants, giving potential to store energy in GWh-sized hot water storages, it proved to not be that easy. Transfer of energy from one sector, such as electricity, to another, district heating, implied tax and cost effects that essentially cancelled out the profitability of the scheme. In this case, the different actors' grid fees played a role but more so the presence of a non-transferable consumption tax on domestic heating companies electricity input that, together with VAT on delivered heat, resulted in a double consumption taxation on both the input and output of the heating companies. Since biofuels, as source for heat, do not have similar taxation it was impossible to compete for the P2P flexibility solution. Thus, the additional income from avoided wind curtailment was lower than the incentive required for district heat companies to run their electric boilers.

Given the highly context specific implementation of the CoordiNet demonstrations for P2P markets no overarching recommendations will be made for necessary support at EU-level based on the demonstration results. In the following an overview of some broader considerations will be given that is supported by the topics review as described in section 2.1.2.

4.5.2.2. General considerations for peer-to-peer market application

Some general considerations regarding the potential for implementing P2P markets, both for energy trading and system services, can be discerned from the literature as well as previous and ongoing pilots. To set up P2P markets there is a need for additional investments (ICT, platforms, smart monitoring, data sharing, etc.). Given the limited experience with this market concept, it is still not clear whether these investments can be retrieved through economic benefits of P2P. As of today, such incentivisation mechanisms are not sufficiently explored. However, before the need for incentivisation schemes can be determined the objectives and potential benefits of implementing this market concept for provision of system services need to be further analysed. Given that the effects of P2P on grid operation and the overall operation of the energy system is still fairly unknown, further investigation is needed to be able to come to any conclusion regarding such a benefit vs impact analysis. In Hayes et. al. (152), the impact of P2P *energy trading* on the operational performance of the distribution network has been analysed. The results suggest that a moderate level of P2P *energy trading* does not have significant impacts on network operational performance, considering a case study of a typical European suburban distribution network. For an overview of the latest work in this area, see Infobox C. The potential impacts of large-scale P2P energy trading or system service provision on network operation and planning remains unclear and too little attention has been paid to the technical constraints of the network under such scenarios.

Infobox C. Overview of some recent work done within the field of P2P markets showing different approaches to considering impacts on network constraints due to the electricity trade.

Recent work addressing the challenge to ensure that market outcomes do not violate network constraints

The study in (153) proposes a local P2P energy market considering network constraints in the market mechanism, whereby the additional costs associated with the technical constraints are internalised in the transactions between the peers. Their methodology considers various coefficients such as voltage, power flows, and losses defined as a function of power injected in the network. These coefficients are embedded in the P2P market to reflect network constraints. The results showed that the proposed method reduces the energy cost of the peers and maintains the local balance between generation and demand without violating network constraints.

The authors of (154) propose a P2P energy market which include network charges using alternative charging methods, i.e., uniformly, based on the electrical distance between agents and by zones. In this case network charges which have been provided ex-ante have been used as incentives to account for grid-related costs in a simple and transparent way, so that market participants are incentivised to respect network constraints. As the network charges are set beforehand, it is important to note that they should be set correctly to allow cost recovery.

Pricing signals are also proposed in the form of network charges which are added to P2P transactions to consider network constraints in (155–158).

All of the above-mentioned examples in the literature follow a preventive approach where P2P trades are conscious of their impact on the network and constraint violation is thus avoided.

Similarly, to other products for flexibility, there is not yet a clear definition of the different roles, rights and responsibilities of actors directly or indirectly involved in P2P. However, before such definitions are made there is a larger need to explore a significant span of different parameters. Looking ahead, a regulatory framework needs to be set up that determines, among other aspects, rights and obligations of peers, consumer-rights, participation criteria, organizational and juridical structure, data, and information sharing among peers and SO requirements. *Here, CoordiNet recommends the creation of regulatory sandboxes to assess the benefits and impacts of P2P seeing that the full range of benefits or impacts of P2P markets are still unknown (Recommendation 5.2).* In future pilots and demonstrations some key questions should be investigated in relation to the potential of system service provision via P2P markets:

- *Investigate ways for P2P markets to offer flexibility to the DSO and TSO.*
- *Define objectives for P2P in system service provision to be able to assess benefits and impacts on the electricity grid.*
- *Assess potential impacts on/off taxation regulation, electricity trade, and grid tariffs.*
- *Investigate if more flexibility service markets, e.g., balancing market products, could be opened up to P2P concepts to increase the possible revenues for the participants.*
- *Analyse the potential benefit for the grid and assets if adapted grid tariffs are required/reasonable.*
- *Develop framework to:*
  - *define rights and obligations of peers*
  - *consumer-rights*
  - *participation criteria*
  - *organisational and juridical structure, and*
  - *operational aspects, such as data and information sharing among peers and SO requirements.*

4.5.3. Theme 5 Recommendations

Table 22. Theme 5 recommendations and list of actions derived from the CoordiNet demonstrations and analyses.

Recommendations	Actions	Level of implementation	Priority
Markets and products for reactive power			
5.1 Due to the immaturity of this service, CoordiNet cannot provide strong recommendations for implementation and regulatory sandboxes should be implemented to allow for additional tests at higher scale. Overall, there are however, some key aspects to take into consideration as the use of this market develops.	Before deciding on a market framework for reactive power products, several market mechanisms need to be explored and evaluated further considering entry costs, price volatility, maturity of the mechanisms, among other relevant criteria.	EU	High
	The coexistence of rules-based and market-based provision of voltage/reactive control services should be enabled to ensure the ability of SOs to choose the most efficient solution in each case.	EU & National	Medium
	Of importance for this specific product is the calculation of voltage sensitivities in relation to reactive power injection/absorption. Since voltage sensitivities depend on grid topology and system state, they should be updated dynamically and continuously to procure the required flexibility. This requires good network monitoring and system state estimation. If this is not possible, voltage sensitivities can be calculated approximately based on grid parameters, using the resistance and reactance of the lines. Even in this case network topology is necessary and therefore voltage sensitivities should be updated when network reconfiguration is applied.	National	Low
	As the monetary threshold for new market participants to provide this service is quite high, and the maturity of this service is low, the return on investment is uncertain. Focus for development should therefore be on R&D pilots primarily.	EU & National	Low
	Communication protocols developed for flexibility services must take into	EU	Medium

	consideration the qualities of voltage control services (see action to recommendation 3.5 in theme 3).		
	Principles for product prequalification developed for flexibility services (see actions to recommendation 4.2 in theme 4) should take into consideration the qualities of reactive power services.	National	Medium
Peer-to-peer markets for flexibility service provision			
5.2 Creation of regulatory sandboxes is recommended to assess the benefits and impacts of P2P	Investigate ways for P2P markets to offer flexibility to DSOs and TSOs.	National	Medium
	Define objectives for P2P in system service provision to be able to assess benefits and impacts on the electricity grid.	EU & National	Medium
	Assess potential impacts on/off taxation regulation, electricity trade, and grid tariffs.	National	Medium
	Investigate if more flexibility service markets, e.g., balancing market products, could be opened to P2P concepts to increase the possible revenues for the participants.	EU & National	Low
	Develop framework to define rights and obligations of peers, consumer-rights, participation criteria, organisational and juridical structure, and operational aspects, such as data and information sharing among peers and SO requirements.	EU & National	Medium

* Business
Techno-economic
Institutional and regulatory
"Social"

5. Conclusions and next steps

This deliverable builds upon conclusion and results from the CoordiNet demonstrations. These results are presented in the CoordiNet Roadmap consisting of five themes, each describing key measures and recommendations that will contribute to the establishment and continuous development of flexibility markets in a European context. The recommendations listed for each theme have been further detailed with specific actions relevant for different domains, i.e., the regulatory, market, technological, and social. Please see Table 6, Table 9, Table 17, Table 20, and Table 22 Table 17in this deliverable for a summary of these recommendations. The CoordiNet Roadmap does provide recommendations, however, without the aim of presenting an exaustive list of what is needed to foster market-based procurement of flexibility for a more efficient and secure future electricity grid. As a next step, the Roadmap may serve as a basis for continous R&D or as an initial list of considerations for other Member States that are starting their work of implementing flexibility markets.

A general conclusion can be made that the CEP has created a solid foundation for flexibility markets to develop. However, implementation is lagging in many Member States which significantly impacts the potential for replicability and scalability of the CoordiNet demonstrations as regulatory provisions are missing on national level to facilitate market implementation. As a part of the Roadmap development interviews and questionnaires with internal and external stakeholders have been performed as a part of the iteration process, making sure the content of the roadmap is relevant in a European context as well as to gain further input. A general result from these activities is that the main conclusion from the demonstration and further analysis presented here is in line with the general opinion and themes highlighted by the majority of engaged stakeholders.

5.1. Incentives to establish and promote participate in flexibility markets

What is evident is that the implementation of the CEP and flexibility markets will affect all SOs but to a larger extent DSOs as they will have to change the approach of their operation. DSOs must change from an asset management approach to a more dynamic system-based approach and work more proactively in terms of grid operation. The Roadmap highlights that for a successful implementation of flexibility markets, DSOs need the right support and economic incentives to be able to establish these markets, but are also dependant on the market liquidity to be able to trust and incorporate flexibility in their planning and operation. Therefore, engagement of FSP in the market, establishing an attractive business case is crucial for the longevity of the markets.

The shift in operation for DSOs will also need to come with a cultural change within organisations in how they plan and manage the grid. For DSOs to manage this change, economic regulation must be revised to support this new approach, going from a CAPEX focused remuneration scheme to also consider the investment needed to implement new markets and procure flexibility services. In addition, CoordiNet recommend that NRAs and public institutions should support the implementation of flexibility markets due to its potential for society wide benefits. Information campaigns, educational opportunities, and support through R&D funds and establishment of regulatory sandboxes will be important strategies to enable this significant shift in electricity market function.

The project highlight that all types of service providers, generation, consumers, prosumers, or storage, should be granted access to markets. Regulatory barriers exist in national regulation for certain type of FSPs which is evident from the SRA carried out within deliverable D6.4 of the project. Thus, it becomes difficult to secure sufficient economic incentives for new participants. This aspect is particularly relevant for scalability and replicability of the CoordiNet BUCs in a wider European context. As mentioned in Theme 2, CoordiNet has to a large extent concentrated and prioritised FSPs size, in terms of electricity consumption, and technology, as this segment has lower market entry barriers than smaller actor and thus easier to engage in the project. However, given that small-scale customers and communities will have a significant role in the future of flexibility markets, aggregation of this segment have also been given significant attention. This segment is however less mature and face some significant market barriers. Thus, a holistic approach to market inclusion should be continuously explored in the future to ensure focus is not only put on possible customers of today but also of the future. We have also seen a need to apply a more holistic approach to what sectures are included when implementing flexibility markets and in the setting of new rules and regulations as well as when reviewing already existing regulation. Expanding the concept from electricity to for instance: mobility, heating, cooling, gas, and hydrogen production to reach the full potential of a flexible energy system.

From the system perspective, little is known of the effects of interfering with the operation of end user components and if they will yield undesired effects on total energy efficiency, technical lifetime, or overall grid costs. In addition, a general note of caution is that the current state of knowledge does not address potential rebound effects. Providing cost reductions or economic benefits from the market could cause rebound effects either by increased consumption of goods (due to lower share of disposable income or monetary capital spent on energy) or causing consumers to consume significantly more in off-peak hours. This could lead to new financial impacts on suppliers and BRPs if they cannot anticipate this, as well as result in unforeseen negative climate impacts. Potential rebound effects must also be further analysed in the domain of how it affects load curves, baselines and thereby an accurate settlement of flexibility procurement, as provision of flexibility can be difficult to track when there is only visibility of the overall load curve of an FSP. This is a question that deserves further investigation. It is important to note however that it is not possible to address overall energy consumption, to ensure the EU reaches its Fit for 55 targets, solely through the integration of higher shares of RES and DER, and implementation of flexibility markets. However, such an analysis lies outside the scope of the CoordiNet Roadmap but is important to highlight for continued development.

5.2. Products and processes

To match the capabilities of the FSPs and SO needs, product harmonisation is an important factor as well as standardised market processes. From the experiences gained within the CoordiNet project it is possible to say that even though EU-wide product harmonisation is needed for flexibility services, strict product standardisation is too early for these markets. As a start, the project concluded that a common terminology, semantics, for flexibility products and services should be developed and implemented on EU level. As national specific contexts makes it difficult to harmonise products across Member States, a list of attributes for the more mature flexibility services, such as congestion management, is recommended for each Member States to define national specific products. Regarding processes, the Roadmap highlights the standardisation of processes for data access, measurement data collection, and interoperability between grid components and market platforms, together with an accelerated deployment of smart-meters as the most important conclusions.

Harmonisation of the market phases prequalification, procurement, and activation as well as settlement should be prioritised to lower entry barriers for participation. For prequalification duplicated processes can be avoided when harmonising processes for product with similar requirements. To then secure a correct bid selection and avoid network violation, CoordiNet is also recommending that some type of network representation should be taken into account in the clearing process, focusing on simplified methods such as impact factors. These factors will help provide enough locational specifics without a detailed digital twin of the grid to match bids with grid needs. Such impact factors should be dynamic to reflect the current situation in the grid.

For a correct settlement process, different baseline methodologies have been proposed and implemented, allowing for the verification of service provision. Here it is important to note that baselines are easier to determine for bulk generation (or large consumers), as these units are usually individually committed in wholesale energy markets. However, for small DERs represented in an aggregated manner there are no individual consumption and/or production commitments making it more complex for aggregators to provide a baseline. To solve this, CoordiNet sees a need to continue to explore this issue to ensure that the provision from aggregated resources can be properly evaluated.

Alternative methods substituting the need of a baseline is also existing, such a Capacity Limitation Services (CLSs). For CLSs, instead of defining the product as a reduction of consumption in terms of energy or power, it establishes a power cap that cannot be surpassed by the end-user, similar to the contracted power limitations that consumers in many countries are subject to. The CLS has the advantage of solving many inherent problems of the baseline calculation (e.g., accuracy, gaming opportunities). However, it also implies the definition of new and potentially more complex market clearing algorithms (159). The CLSs is not a methodology tested in the CoordiNet project but could be an alternative to include in future pilots and flexibility market projects

5.3. New innovative market concepts

Regarding more innovative market-based concept that are in early development stages, as market-based procurement of reactive power and P2P markets for system services that has been tested, more research has to carried out for these concept to reach a commercial level of matureness. Therefore, further investigation is recommended for the two concepts where regulatory sandboxes and R&D funds will come to be an important factor for their further development.

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APPENDIX A: POLICY RELEVANT DOCUMENTS INCLUDED IN THE LITTERATURE REVIEW

In the screening process a selection of regulatory documents, European organisation reports as well as position, white and discussion papers were chosen for review. The chosen documents are listed below in Table A.

Table A. Overview of documents of regulatory importance included in the screening.

Organisation	Title	Type of document
Regulatory documents		
European Parliament	2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity	Regulation
European Parliament	2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity	Directive
European Commission	2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC	Directive
European Commission	2017/1485 - of 2 August 2017 - establishing a guideline on electricity transmission system operation	Regulation
European Commission	2017/2195 of 23 November 2017 establishing a guideline on electricity balancing	Regulation
European Commission	2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management	Regulation
European Commission	2016/631 - of 14 April 2016 - establishing a network code on requirements for grid connection of generators	Regulation
European Commission	2016/1388- of 17 August 2016 - establishing a Network Code on Demand Connection	Regulation
ACER	Methodology for a list of standard products for balancing capacity for frequency restoration reserves and replacement reserves	Decision No 11/2020 of the European Union Agency for the Cooperation of Energy Regulators of 17 June 2020
CENELEC	European Standard EN50160 Voltage characteristics of electricity supplied by public distribution systems	Standard
Reports published by EU/National organisations		
CEDEC eurelectric, E.DSO, Geode	Flexibility in the Energy Transition: Toolbox for Electricity DSOs	Report

CEDEC, E.DSO, eurelectric, Geode	Smart Grid Key Performance Indicators: A DSO perspective	Proposal for indicators to measure the performances of smart grids
CEER (Distribution Systems Working Group)	Flexibility Use at Distribution Level	Conclusion paper from public consultation
ENTSO-E	All TSOs' proposal for the Key Organisational Requirements, Roles and Responsibilities (KORRR) relating to Data Exchange in accordance with Article 40(6) of Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a Guideline on Electricity Transmission System Operation	Common proposal
ENTSO-E, CEDEC, E.DSO, Eurelectric, GEODE	Roadmap on the Evolution of the Regulatory Framework for Distributed Flexibility A joint report by ENTSO-E and the European Associations representing DSOs	Joint report
smartEn	The implementation of the electricity market design to drive demand-side flexibility	Monitoring report
FERC	Payment for Reactive Power	Commission Staff Report
ENTSO-E, Working Group Ancillary Services	Survey on ancillary services procurement, balancing market design 2019	Survey report
CENELEC	European Standard EN50160 Voltage characteristics of electricity supplied by public distribution systems	Standard
CEER	Flexibility Use at Distribution Level	Conclusion paper from public consultation
ENTSO-E	Options for the design of European Electricity Markets in 2030	Discussion Paper for Stakeholder Consultation
CEDEC, E.DSO, ENTSO-E, Eurelectric, Geode	An integrated approach to active system management with the focus on TSO-DSO coordination in congestion management and balancing	Joint report
ISGAN Annex 6	Flexibility needs in the future power system	Report
CIGRE	Benchmark Systems for Network Integration of Renewable and Distributed Energy Resources	Brochure
CEN, CENELEC, ETSI	Smart Grid Coordination Group. Smart Grid Reference Architecture	Framework for standard enhancement in the field of smart grids
BEUC	Electricity aggregators: starting off on the right foot with consumers	Recommendations for regulators
European Smart Grids Task Force Expert Group 3	Demand Side Flexibility: Perceived barriers and proposed recommendations	Report
Swedish Energy Markets Inspectorate	Measures to increase demand side flexibility in the Swedish electricity system	Proposal of measures to increase demand side flexibility in the Swedish electricity system

Position/White paper		
USEF	Flexibility platforms	White paper
USEF	The aggregator	Position paper
USEF	Workstream on aggregator implementation	Recommendations for regulators
ENEROC	The Demand Response Baseline	White paper
NODES	Paving the way for Flexibility	White paper
Europex	Call for Harmonised Implementation of the Clean Energy Package: Independent Aggregation Rules to Unlock Full Potential of Demand-side Flexibility	Position paper
Elia	Design note: Transfer of Energy in DA and ID markets Market Development [	Report
Elia	Towards a consumer-centric and sustainable electricity system	White paper

APPENDIX B: THEMES LIST

Common vs separate markets
Clear advantages/disadvantages of common[1] vs. separate market models.

- What advantages/disadvantages are mentioned? What is the reasoning behind?
- What could be possible barriers for the implementation of each market model?
- Are there any recommendations regarding market hierarchy, TSO-DSO governance, in a separate market model? (e.g. bid forwarding from DSO to TSO, independent TSO and DSO market platforms, required communication and sharing of information etc.

Procurement of capacity vs energy
Benefits and added value for the possibility of procuring capacity vs energy.

- Are there any specific needs mentioned for the procurement of capacity compared to energy only? If yes, what is the reasoning behind?
- Are there any barriers defined for selling and buying capacity compared to energy only?

Timing aspects of the market
Important timing aspects to be set for the market.

- Are there any recommendations on market closing and clearing times? Make a distinction between the procurement of capacity and energy only where appropriate.

Timing aspects of the integration with other markets
Implementation of a flexibility market with regard to the timing of other markets (wholesale and balancing).

- Are there any recommendations / best practices regarding the timeline of flexibility markets with respect to other markets (energy markets, ancillary services markets, redispatch mechanisms,…)?
- What could be the risks if the markets overlap?

Market clearing/bid selection and pricing
Preferable clearing method/bid selection and pricing mechanism.

- Which information is considered in the proposed clearing method/bid selection (prices, network impact,…)?
- What are recommendations regarding the selection and optimization model by the SO?

Requirements for information sharing
Information level to be shared between the participants of the market.

- Are there any recommendations regarding the kind of information to be shared between the DSO, TSO, other actors? Make a distinction between the different market phases if possible (prequalification, procurement, activation, settlement).
- Are there any barriers identified with regard to security and confidentiality of data?

Roles and responsibilities
Roles and responsibilities divided between DSO, TSO and other participants in the markets.

- Are there any recommendation about the Data manager role? Which actor should take up this role (DSO, TSO, independent actor)? What are its main tasks with respect to the validation of flexibility delivery?
- Are there any recommendation about the Market operator role? Which actor should take up this role (DSO, TSO, independent actor)?

Requirements of prequalification process
Prequalification requirements that are set on the market participants.

- What prequalification requirements are identified for different products/services of the FSPs?
- Are there any recommendations of standardisation of the process or additional/less requirements? What is the reasoning behind this?

Aggregation
Framework requirements for independent aggregation to create a more liquid market that entices all types of FSPs.

- Under which circumstances and conditions are aggregators allowed to participate?
- Is there a framework in place / proposed to allow for independent aggregation (incl. Transfer of Energy/perimeter correction)? If so, how is the assignment of deviations between actors for entering the role of an independent aggregator described?
- Are there any barriers defined on what assets (generation/load/storage) can be aggregated?

Geographical scope and network representation
Representation of geographical location of assets and grid structure in the market.

- Is the network representation part of the market clearing? If yes, which information is used? If no, how is the network or how are constraints accounted for?
- Any recommendations or barriers identified?

Grid decision support tools
Supplementary tools at the DSO/TSO side which complement the market platform (e.g. forecasting tools,…)

- Which supplementary tools are considered? What is their main objective?

Consumer engagement
Consumer engagement to entice all market participants to create a liquid flexibility market.

- Are there any recommendations on how to make a market accessible for all type of consumers?
- What factors are valuable/tipping points for the customers to participate?
- Are there any recommendations on how to engage consumers in the longer run (consumer retention)?
- Are specific business models proposed at the consumer side (e.g. by aggregators)?

Specific topics for innovative market pilots

Markets and products for reactive power

- What are the design characteristics of markets for reactive power researched / piloted in other projects?
- What are the main challenges when setting up a market for reactive power?
- Are any reasons given why market-based procurement methods do not work for reactive power? Which alternatives are proposed (rule-based, cost-based…)?

P2P markets for system services

- What are the design characteristics of P2P markets for system services researched / piloted in other projects or described in literature?

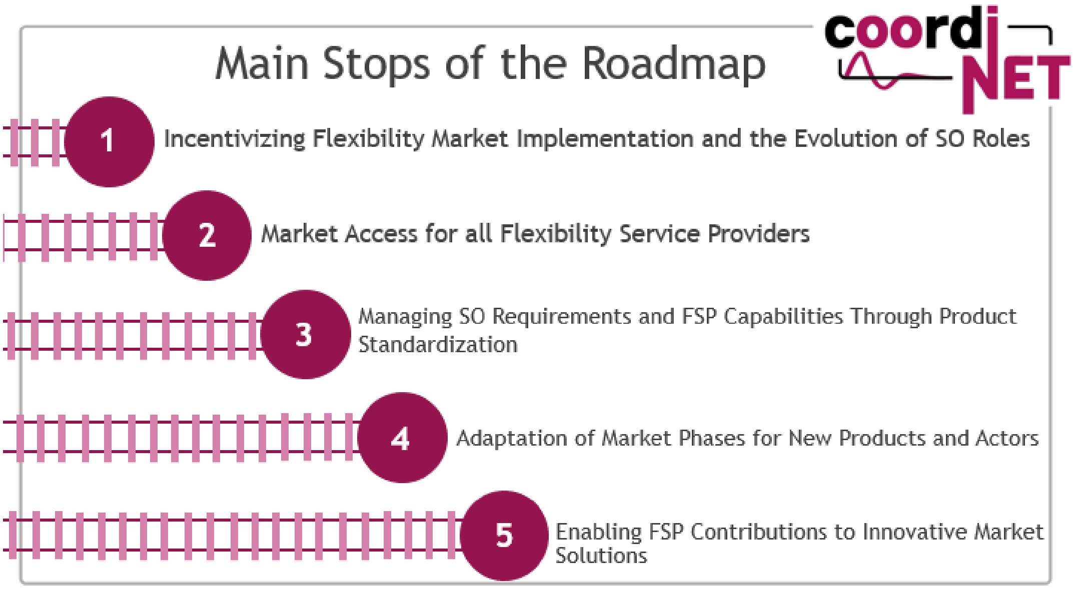
- How do P2P markets for system services link with existing markets for system services?
- How does the role of traditional actors on existing system service markets change in/with respect to P2P markets for system services?
- What are the main challenges when setting up P2P markets for system services?

APPENDIX C: QUESTIONS USED FOR QUESTIONNAIRES AND IN-DEPTH INTERVIEWS

The CoordiNet project will help to demonstrate how DSOs and TSOs shall act in a coordinated manner and use the same pool of resources to procure system services most reliably and efficiently through the implementation of large scale "TSO-DSO-Consumer" demonstrations, in cooperation with market participants (and end-users).

The purpose of CoordiNet is to establish different collaboration schemes between transmission system operators (TSOs), distribution system operators (DSOs) and consumers to contribute to the development of a smart, secure, and more resilient energy system. Special emphasis will be on the analysis and definition of flexibility in the grid at every voltage level ranging from the TSO and DSO domain to consumer participation.

CoordiNet is now summing up the main conclusions and recommendations in a roadmap towards a new market design. These interviews aim to get additional input on key questions raised in the roadmap.



1. **The CoordiNet Roadmap considers several aspects, all important for the development of flexibility markets for system services and their scale-up in Europe. Which of these aspects do you perceive to be the most challenging to reach?**
    a) Proper incentives to establish markets for flexibility procurement by DSOs/TSOs
    b) Clear roles and responsibilities within flexibility markets
    c) Flexibility product definition and standardization
    d) Flexibility market definition and standardization
    e) Eliminating entry barriers for FSPs to participate in flexibility markets

Theme 1: Incentivizing Flexibility Market Implementation and the Evolution of SO Roles

Here we looked closer into the new challenges that DSOs and TSOs need to overcome to establish new flexibility markets. What distinguishes this stop is how the system operators' roles and responsibilities will come to change and the need for increased coordination this will result in.

2. **Which change do you believe is needed for DSOs and TSOs to be able to develop flexibility markets for system services?**

Alternatives used in the questionnaire.

a. Implementation of regulatory incentives that would make investments in flexibility solutions financially viable in relation to grid reinforcement, such as adaptation of remuneration schemes to enable cost recovery
b. Change of business operation of the DSOs and TSOs from resource-driven to a more consumer-driven
c. Other

If other, please specify:

3. System operators will take on new roles in the development of flexibility markets. What is your preference on who should take on the role of the market operator in these markets?

Alternatives used in the questionnaire.

a. The system operator (TSO or DSO)
b. An independent market operator would be preferred
c. Both, depending on the situation
d. Don´t know

Please elaborate your answer:

4. What is your preference regarding who should take on the role of data manager in the context of flexibility markets?

Alternatives used in the questionnaire.

e. The system operator (TSO or DSO)
f. An independent data manager would be preferred
g. Don´t know

Please elaborate your answer:

5. What key success factors, for implementation of flexibility markets, from the perspective of the DSOs and TSOs do you see as most important?

Theme 2: Market Access for all Flexibility Service Providers

This stop focuses on the FSP perspective. What is important is that we strive to make the markets easy to access for all types of flexibility providers to be able to meet the growing demand for flexibility.

6. Which entry and operational barriers for flexibility service providers do you believe will be the hardest to overcome?

Alternatives used in the questionnaire.

Please assign each option low/medium/high to indicate level of difficulty to overcome

a. Poor business case due to for example high entry costs and/or upfront necessary investments
b. Regulatory barriers which limit certain flexibility services provider types
c. Product requirements that hinders equal access to the market for all types of flexibility service providers
d. Low knowledge and understanding of how to participate in flexibility markets
e. Highly complex prequalification process

f. Potential negative effects on flexibility providers due to participation, for example impact on the core business or impact on comfort levels
g. Lack of trust in the DSO/TSO as transparency of the market is perceived as low.
h. Other:

If other, please specify:

7. **The CoordiNet results highlight the importance of implementation of the independent aggregator role for increased market liquidity. What do you think is necessary to support the implementation of this role as mandated in the Clean Energy Package?**

Theme 3: Managing SO Requirements and FSP Capabilities Through Product Standardisation

This stop is a combination of the previous two stops and looks at how requirements for flexibility services can be matched with FSPs capabilities through different levels of standardisation of products and processes.

8. **What would be the most important areas for standardisation to enable scale up of flexibility solutions such as congestion management markets for the DSO across Europe? And on what level?**
Please assign each area a level of importance and indicate the level of standardisation which should be targeted from your point of view.

Area to standardise	**Importance** (low/medium/high)	**Level of standardisation** (EU level/national level/a mix of both/no standardisation)	**Comments**
Roles and responsibilities			
Products			
Platform design			
Interfaces and data protocols			
Market design			
Integration of the timing of the flexibility market(s) within the timing of existing markets			
Prequalification processes			
Settlement processes			
Baseline methodology			

Data requirements and metering equipment			
Implementation of smart meters, IoT devices			

9. **What level of product standardisation do you foresee (e.g., specific products for a specific System Operator, common products for all DSOs and/or TSOs in a country, common products across countries, one product covering multiple services,…)?**

10. **In your point of view, do you think a long-term product (year, month, week ahead) will be necessary in addition to short term products in congestion management markets? (Yes/No)**

    If yes, please explain why:

Theme 4: Adaptation of Market Phases for New Products and Actors

This stop focuses on the necessary adaptations of market phases that would be necessary for a well-functioning flexibility market.

11. **In relation to alignment and timing, what do you see as key factors (other than standardisation) for the integration of new flexibility markets for system services with already established wholesale and balancing markets?**

12. **In the prequalification market phase, what do you see as the key factor to engage more flexibility service providers in flexibility markets? (Examples could include: automatic processes or having one prequalification process for several services.)**

13. **What level of network representation do you see as necessary in the flexibility to secure a correct and transparent bid selection?**
    Alternatives used in the questionnaire:
    i. A full representation of the grid is necessary
    j. A simplified network representation is sufficient, for example sensitivity factors
    k. No network representation is necessary
    l. Other
    If other, please specify:

14. **In the settlement market phase, what do you see to be of the greatest importance to enable correct verification of delivered flexibility? (Examples could be: a correct provision of baseline, availability of smart meter data or access to additional measurement data such as sub-metering)**

15. **What do you see as advantages/disadvantages to a separate market model (one sole buyer e.g., the DSO) vs a common market model (several buyers, e.g., DSO and TSO) when designing a flexibility market for system services? Please also indicate if the preference is connected to a specific service.**

Theme 5: Enabling FSP Contributions to Innovative Market Solutions

This stop looks at the possibility to extend FSP contributions to other market-based services and P2P markets for system services.

16. What is your view on market-based solutions for different types of system service? What level of maturity will the service need to reach? And for what system operator would this be the best solution?

Please indicate your answers in the table below.

System service	Market-based solution (Yes/No)	System operator (DSO/TSO/both DSO and TSO)	Level of maturity on service (low/medium/high)
Congestion management			
Balancing			
Voltage control			
Controlled islanding			

17. Do you see a value in setting up peer-2-peer markets for system services?

Overarching questions

18. Are there any other aspects you would like to highlight as of special importance for the CoordiNet roadmap?

APPENDIX D: DEFINITION OF PRODUCT CHARACTERISTICS

Table 3-2: Definition of product characteristics

Characteristic	Definition	Source
Preparation period	The period between the request by the SO and the start of the ramping period.	Adapted from (European Commission, 2017a)
Ramping period	The period during which the input and/or output of power will be increased or decreased until the requested amount is reached.	Adapted from (ENTSO-E, 2018d)
Full activation time	The period between the activation request by the SO and the corresponding full delivery of the concerned product.	Adapted from (European Commission, 2017a)
Minimum/maximum quantity	The power (or change in power) which is offered, and which will be reached at the end of the full activation time. The minimum quantity represents the minimum amount of power for one bid. The maximum quantity represents the maximum amount of power for one bid.	Adapted from (ENTSO-E, 2018d)
Minimum/maximum duration of delivery period	The minimum/maximum length of the 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 (European Commission, 2017a)
Deactivation period	The period for ramping from full delivery to a set point, or from full withdrawal back to a set point.	Adapted from (European Commission, 2017a)
Granularity	The smallest increment in volume of a bid.	Adapted from (ENTSO-E, 2018d)
Validity period	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[8].	Adapted from (European Commission, 2017a)
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 request of the SO.	Adapted from (European Commission, 2017a)
Availability price	Price for keeping the flexibility available (mostly expressed in € /MW/hour of availability)	
Activation price	Price for the flexibility actually delivered (mostly expressed in € /MWh)	
Divisibility	The possibility for a system operator 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 (European Commission, 2017a)
Locational 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...)	
Recovery period	Minimum duration between the end of deactivation period and the following activation.	Adapted from (European Commission, 2017a)
Aggregation allowed	This attribute determines whether a grouped offering of power by covering several units via an aggregator is allowed.	
Symmetric/asymmetric product	This attribute determines whether only symmetric products or also asymmetric products are allowed. For a symmetric product upward regulation volume and downward regulation volume has to be equal.	Adapted from (ENTSO-E, 2018f)