Smart TSO-DSO interaction schemes, market architectures and ICT Solutions for the integration of ancillary services from demand side management and distributed generation

Basic schemes for TSO-DSO coordination and ancillary services provision

D1.3

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About SmartNet

The project SmartNet (http://smartnet-project.eu) aims at providing architectures for optimized interaction between TSOs and DSOs in managing the exchange of information for monitoring, acquiring and operating ancillary services (frequency control, frequency restoration, congestion management and voltage regulation) both at local and national level, taking into account the European context. Local needs for ancillary services in distribution systems should be able to co-exist with system needs for balancing and congestion management. Resources located in distribution systems, like demand side management and distributed generation, are supposed to participate to the provision of ancillary services both locally and for the entire power system in the context of competitive ancillary services markets.

Within SmartNet, answers are sought for to the following questions:

- Which ancillary services could be provided from distribution grid level to the whole power system?
- How should the coordination between TSOs and DSOs be organized to optimize the processes of procurement and activation of flexibility by system operators?
- How should the architectures of the real time markets (in particular the markets for frequency restoration and congestion management) be consequently revised?
- What information has to be exchanged between system operators and how should the communication (ICT) be organized to guarantee observability and control of distributed generation, flexible demand and storage systems?

The objective is to develop an ad hoc simulation platform able to model physical network, market and ICT in order to analyze three national cases (Italy, Denmark, and Spain). Different TSO-DSO coordination schemes are compared with reference to three selected national cases (Italian, Danish, and Spanish).

The simulation platform is then scaled up to a full replica lab, where the performance of real controller devices is tested.

In addition, three physical pilots are developed for the same national cases testing specific technological solutions regarding:

- monitoring of generators in distribution networks while enabling them to participate to frequency and voltage regulation,
- capability of flexible demand to provide ancillary services for the system (thermal inertia of indoor swimming pools, distributed storage of base stations for telecommunication).

Partners

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List of Abbreviations and Acronyms

Acronym	Meaning
ACER	Agency for the Cooperation of Energy Regulators
aFRR	Automatic Frequency Restoration Reserves
AS	Ancillary Services
BRP	Balance Responsible Party
CACM	Capacity Allocation and Congestion Management
CEER	Council of European Energy Regulators
CMP	Commercial Market Party
DCC	Demand Connection Code
DER	Distributed Energy Resources
DG	Distributed Generation
DM	Data Manager
DRES	Distributed Renewable Energy Sources
DSM	Demand Side Management
DSO	Distribution System Operator
Dx	Distribution grid
EB	Electricity Balancing
EEGI	European Electricity Grid Initiative
ENTSO-E	European Network of Transmission System Operators for Electricity
ER	Emergency and Restoration
EU	European Union
FCA	Forward Capacity Allocation
FCR	Frequency Containment Reserves
FD	Flexibility Dispatcher
FFC	Flexibility Feasibility Checker
FRR	Frequency Restoration Reserves
GBR	Grid Balance Responsible
HV	High Voltage
HVDC	High Voltage Direct Current
ISGAN	International Smart Grid Action Network
IEM	Internal Electricity Market
IMO	Independent Market Operator
mFRR	Manual Frequency Restoration Reserves
NC	Network Code
NRA	National Regulatory Authority
MDR	Metered Data Responsible
MO	Market Operator
MS	Member State

MV	Medium Voltage
RA	Reserve Allocator
R&D	Research and Development
RfG	Requirements for generators
RR	Replacement Reserves
SBR	System Balance Responsible
SGU	Significant Grid User
SO	System Operator/ System Operation
SoS	Security of Supply
TSO	Transmission System Operator
Tx	Transmission grid
UC	Use Case

Executive Summary

The energy market is undergoing important changes, driven by the realization of the European internal energy market on the one hand and the increase of distributed energy resources (DER) on the other hand. The significant amount of DER, mainly connected at the distribution grid, results in a higher need for flexibility services for system operators (TSOs and DSOs) and other commercial market parties (i.e. balance responsible parties (BRPs)). Flexibility is needed in case of large deviations in e.g. wind and solar production, or demand. In these situations, flexibility could be used, in order to control and restore the frequency and the voltage of the grid, to balance the individual portfolios or to manage congestion.

The increase of DER connected at the distribution grid provides an additional opportunity for system operators to use these resources for services such as frequency control, voltage control and congestion management, both at the distribution and transmission grid.

Today, resources from the distribution grid are starting to participate to the TSO ancillary services (AS) markets. However, the participation is still limited and there is a wide variety in products and rules across countries. DSOs use rarely flexible resources to solve local network problems. In case the TSO uses resources from the distribution grid, this service is mainly organized without any involvement of the DSO, which could potentially lead to problems in case of increasing volumes. The need for increased cooperation between system operators is recognized by several stakeholders and the EU regulation (Network Codes (NCs)) provides a first basic framework to develop further collaboration structures.

Five coordination schemes are proposed that present different ways of organizing the coordination between system operators. Each coordination scheme is characterized by a specific set of roles, taken up by system operators, and a detailed market design. The differences between the coordination schemes have mainly an impact on the procurement phase of the AS or local system services. The processes of prequalification, activation and settlement of flexible resources are rather similar across coordination schemes due to the fact that the roles responsible for these activities are undoubtedly assigned to a specific market party.

In the *Centralized AS market model*, the TSO operates a market for both resources connected at transmission and distribution level, without extensive involvement of the DSO. In the *Local AS market model,* the DSO organizes a local market for resources connected at the DSO-grid and, after solved local grid constraints, aggregates and offers the remaining bids to the TSO. In the *Shared balancing responsibility model,* balancing responsibilities are divided between TSO and DSO according to a predefined schedule. The DSO organizes a local market to respect the schedule agreed with the TSO while the TSO has no access to resources connected at the distribution grid. In the *Common TSO-DSO AS market model,* the TSO and the DSO have a common objective to decrease costs to satisfy both the need for resources by the TSO and the DSO. This common objective could be realized by the joint operation of a common market (centralized variant) or the dynamic integration of a local market, operated by the DSO,

and a central market, operated by the TSO (decentralized variant). In the *Integrated flexibility market model*, the market is open for both regulated (TSOs, DSOs) and non-regulated market parties (BRPs, CMPs), which requires the introduction of an independent market operator to guarantee neutrality.

The different coordination schemes all have specific benefits and attention points related to the TSO grid operation, the DSO grid operation, other market participants involved and the market operation in general. The table below summarizes the main benefits and attention points for each scheme for the different stakeholders.

Coordination Scheme	Benefits	Attention points
Centralized AS market model	▪ Efficient scheme in case only the TSO is a buyer for the service ▪ A single market is low in operational costs and supports standardized processes ▪ Most in line with current regulatory framework	▪ No real involvement of DSO ▪ DSO grid constraints not always respected
Local AS market model	▪ DSO has priority to use local flexibility ▪ DSO supports actively AS procurement ▪ Local markets might create lower entry barriers for small scaled DER	▪ TSO and DSO market cleared sequentially ▪ Local markets might be rather illiquid ▪ Need for extensive communication between the TSO market and the local DSO markets
Shared balancing responsibility model	▪ The TSO will need to procure a lower amount of AS ▪ Local markets might create lower entry barriers for small scaled DER ▪ Clear boundaries between system operation TSO and DSO	▪ Total amount of AS to be procured by TSO and DSO will be higher in this scheme ▪ BRPs might face higher costs for balancing ▪ Small local markets might be not liquid enough to provide sufficient resources for the DSO ▪ Defining a pre-defined schedule methodology agreed by both TSO/DSO might be challenging
Common TSO-DSO AS market model	▪ Total system costs of AS for the TSO and local services for the DSO are minimized ▪ TSO and DSO collaborate closely, making optimal use of the available flexible resources	▪ Individual cost of TSO and DSO might be higher compared to other schemes ▪ Allocation of costs between TSO and DSO could be difficult
Integrated flexibility	▪ Increased possibilities for BRPs to solve imbalances in their portfolio	▪ Independent market operator needed to operate the market platform

market model	▪ High liquidity and competitive prices due to large number of buyers and sellers	▪ Negative impact on the development and liquidity of intraday markets ▪ TSO and DSO need to share data with IMO

In addition, the feasibility of the implementation of each coordination scheme is very dependent on the regulatory framework. Today, the Centralized AS market model is most in line with current regulations. The other coordination schemes require each extensive changes with respect to roles and responsibilities of TSO and DSO. The implementation of a coordination scheme is also influenced by the national organization of TSOs and DSOs, i.e. the amount of system operators and the way they currently interact. In addition, the installation of certain coordination schemes will have an impact on other markets such as the intraday markets. Dependent on the services offered in the AS market, compared to the intraday markets, these markets might be able to co-exist or alternatively, need to be integrated.

1 Introduction

The growing share of distributed energy resources (DER) in the distribution grid provides opportunities to use these resources for the provision of services not limited to the distribution grid, but for the overall benefit of the entire power system. Procurement of flexibility-based services (e.g. ancillary services for the TSO or local system services for the DSO), delivered by resources directly connected at distribution grid level, requires optimal coordination between the transmission system operator (TSO) and the distribution system operator (DSO). Within this report, different modalities for the coordination between TSOs and DSOs are examined.

1.1 Objectives and report structure

The present deliverable has the following objectives:

- Propose a representative set of basic TSO-DSO coordination schemes for the provision of flexibility-based services for system operators (e.g. ancillary services (AS) for the TSO and local system services for the DSO) by resources (i.e. distributed generation (DG), demand side management (DSM) and storage) directly connected to the distribution grid;
- Illustrate the framework for each coordination scheme focusing on (1) the envisioned set of roles and responsibilities, (2) potential market architectures and (3) relevant information exchanges by applying the coordination schemes on a selection of use cases (UCs).
- Compare the different coordination schemes and assess the benefits, attention points and feasibility of each coordination scheme.

Details on the coordination schemes, discussed within this deliverable, serve as input for the design of adapted markets and the definition of ICT requirements.

Outcomes from the present deliverable are also used for developing national cases, setting-up pilots and describing potential implications related to the implementation of TSO-DSO coordination schemes.

The document is structured according to the following chapters:

- Chapter 1 presents an introduction to the scope, objectives and structure of this report.
- Chapter 2 describes the methodology used for the selection and assessment of the TSO-DSO coordination schemes.
- Chapter 3 provides the results of both a literature review and a country survey, related to current practices and expected evolutions on TSO-DSO coordination.

- Chapter 4 introduces a selection of coordination schemes: general principle, roles, responsibilities and market architecture. A set of use cases is examined in the context of different coordination schemes.
- Chapter 5 analyses and compares different coordination schemes. The main benefits and risks of each of the coordination schemes are highlighted and the feasibility of each of the coordination schemes is discussed.
- Chapter 6 gives an overview of the main conclusions and key messages.

References and appendices are presented in Chapter 7 and Chapter 8.

2 Methodological approach

The following chapter describes the methodology used to define the different coordination schemes. In addition, a selection of use cases is presented that will be analyzed for the different coordination schemes.

2.1 Selection of coordination schemes

The selection of relevant coordination schemes is based on a literature review, a country survey, a theoretical analysis and a public consultation. The process and the relationship between these sources are shown in ***Figure 1***.

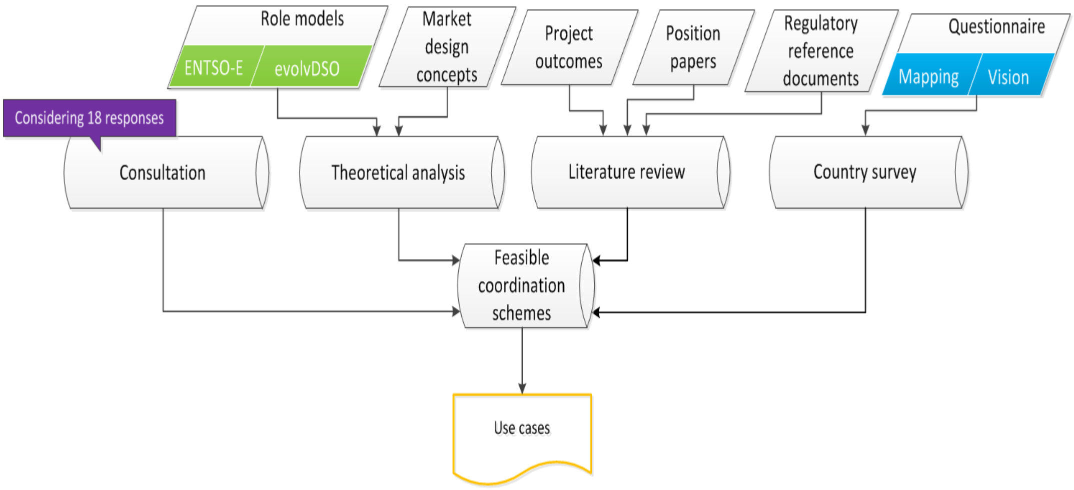

Figure 1 Methodology

The literature review examines existing needs and recommendations on the future needs of cooperation between TSOs and DSOs. Several distinct sources are used as input:

- Regulatory reference documents, i.e. European and national network codes[1], European directives related to energy policy[2], …;
- Position papers from various power system stakeholders, e.g. ACER, CEER, EDSO for Smart Grids, ENTSO-e, Eurelectric, Smart Grid Task Force;

[1] EU network codes can be found in ENTSO-E network codes. National network codes may be found in the website of the respective TSO.
[2] e.g. the Energy Efficiency Directive [1]

- Outcomes (results and recommendations) of projects at European and national level. Only projects that showed a direct link with the subject of study, i.e. TSO-DSO coordination schemes, were analyzed. Sources to these projects were provided by SmartNet partners.[3]

The country survey has collected information via a questionnaire from a selection of countries, represented in the SmartNet consortium: Austria, Belgium, Denmark, Finland, Italy, Norway and Spain. The questionnaire is structured in two differentiated sections:

a. The first section is dedicated to the mapping of existing TSO-DSO interaction schemes with respect to procurement and activation of distributed energy resources (DER), including storage, distributed generation (DG) and demand response (DR), directly connected to the distribution grid.

- The second section assesses possible alternative coordination schemes and innovative concepts for future TSO-DSO cooperation.

In addition to the literature review and the country survey, a critical assessment has been made about potential additional alternative TSO-DSO coordination schemes, based upon existing role models for TSOs and DSOs on the one hand and existing concepts of market design on the other hand (e.g. centralized versus decentralized). The role models considered are the TSO role model as proposed by [10] and the DSO role model as developed in the FP7 project EvolvDSO [11].

A consultation was organized related to possible coordination schemes between TSOs and DSOs in the context of ancillary services provision. The consultation asked specific questions related to the role of system operators, the appropriate market design, the relevant use cases and the feasibility of the coordination schemes. Respondents could provide answers via the project website or by email for a period of 2 months. Nineteen answers were received in total. Eighteen answers were considered complete and the feedback is integrated in the report. In appendix 8.2, the questions of the consultation are presented. In appendix 8.3, an overview is given of the different respondents to the consultation.

[3] CITIES [2], FlexPower [3], IEA-ISGAN [4], evolvDSO [5], CHPCOM [6], SGEM [7], FENIX [8], ADDRESS [9].

2.2 Assessment of coordination schemes

The different coordination schemes are examined in terms of benefits and risks. The analysis comprises two steps:

1. Selection and description of relevant services (use cases[4]) that highlight the main differences between coordination schemes.

   The selection and description of use cases is done in cooperation with consortium members involved in the definition of flexibility-based services for system operators for future European power systems [12]. Current and future flexibility-based services were listed. Only the services that are expected to be mature by 2030 and procured via a market-based environment were selected for further analysis. For each service selected, use cases are defined that describe the information exchange between market parties for the prequalification, procurement, activation and settlement of a specific service, according to the SGAM framework [13]. Use cases are further used in the definition of the ICT requirements.

2. Analysis of internal and external aspects of coordination schemes, taking into account the different phases of procurement and activation of flexibility-based services.

The analysis focuses first on the impact of a specific coordination scheme on TSO grid operation, DSO grid operation, the role of other market participants and the related market design (internal aspect). In addition, the relations between the coordination schemes and the national regulatory framework and the European evolution are assessed (external aspect).

[4] Within SmartNet, a use case is defined as the provision of a service, within the framework of a certain coordination scheme, from one actor to another actor.

3 Framework for the provision of flexibility-based services by DER

In order to describe the context for the provision of flexibility-based services by DER directly connected to the distribution grid, two main sources were used: a literature review and a country survey.

The literature review provides an overview of the current status of regulatory measures at European level. The overview is complemented with a description of stakeholders' positions concerning cooperation between system operators and the need to make flexibility-based services available across the entire power system.

The objective of the literature review is to create an overview of the current status of TSO-DSO interactions and outline their future needs, taking into account current regulatory boundaries. The literature review, as mentioned in chapter 2, is intended to function as a basis and reference for the creation of coordination schemes. These schemes are then further discussed in chapter 4.

The study concentrates on specific actions, documents and public statements from key stakeholders involved in the discussion around TSO-DSO cooperation. Relevant conclusions from Research and Development (R&D) projects and national processes follow the summary of stakeholders' positions. This is done in order to provide an overall view of the current perspectives around flexibility use and coordination among system operators.

The stakeholders considered within this analysis are listed below:

- Regulators
    - National Regulatory Agencies (NRAs);
    - Agency for the Cooperation of Energy Regulators (ACER);
    - Council of European Energy Regulators (CEER)
- System operators associations
    - European Network of Transmission System Operators (ENTSO-E);
    - European associations representing DSOs: EDSO for Smart Grids, Eurelectric, GEODE and CEDEC;
- Other
    - European Grid Electricity Grid Initiative (EEGI);
    - International Smart Grid Action Network (ISGAN);
    - Consortia of European projects.

Sections 3.1 and 3.2 discuss more in detail the European regulatory context and the positions of different stakeholders, in relation to the coordination between TSOs and DSOs.

The country survey illustrates current practices concerning the services provided by DER services within seven European countries. The country survey is further complemented with insights on innovative concepts with potential application to coordination schemes for system operators. The country survey is presented in section 3.3.

3.1 European regulatory context: a literature review

The need for increased cooperation between TSOs and DSOs is widely recognized by regulators. DSOs and TSOs should significantly increase engagement with one another to deliver the best whole system outcome for customers [14]. In previous years, progress has been made to create an appropriate framework for further cooperation between TSOs and DSOs. Proof of this are the adaptions made to current network codes.

Network codes are developed at European level. NCs provide rules for a wide variety of areas, e.g. network security, reliability and connection, third-party access, data exchange and settlement, emergency procedures, balancing including network-related reserves, etc. These rules address issues related to the proper functioning of the internal electricity market (IEM). To this end, system security should be guaranteed, transparency should be enforced and optimal grid operation should be kept taking into account highest overall efficiency and lowest total cost for all involved parties [15].

TSO-DSO cooperation is not explicitly addressed in the NCs. However, several topics discussed in these codes impact directly or indirectly how system operators cooperate. ***Table 1*** provides an overview of the network codes highlighting their relevancy with respect to TSO-DSO cooperation. NCs that still have to pass the validation process may suffer some adaptations. An up-to-date status of the NCs can be found in [16]. The provisions determined in the NCs are not exhaustive and should be considered as a basis on which future cooperation between TSOs and DSOs should be built [14].

Category	Network Code / Guideline	Status	Relevant to TSO-DSO coordination discussion
Connection	Requirements for Generators (RfG)	Into force (5/2016)	Yes
	Demand Connection (DCC)	Into force (8/2016)	Yes
	High Voltage Direct Current (HVDC)	Into force (8/2016)	Limited

Operation	System Operation (SO)[5]	Validated by EU MS. Awaiting validation by European Commission	Yes
	Emergency and Restoration (ER)	Awaiting validation by EU MS	Yes
Market	Capacity Allocation and Congestion Management (CACM)	Into force (8/2015)	No
	Electricity Balancing (EB)	Awaiting validation by EU MS	Yes
	Forward Capacity Allocation (FCA)	Validated by EU MS. Awaiting validation by European Commission	No

Table 1 Network Codes status and relevancy towards TSO-DSO coordination

The above listed NCs are grouped in 3 categories: Connection, Operational and Market codes.

3.1.1 Network codes related to Connection

The codes included in the Connection category are Requirements for Generators (RfG), Demand Connection (DCC) and High Voltage Direct Current (HVDC). In general, these NCs count on system operators to define requirements and to assess the potential impact a connection of a specific resource may have on their system. These actions are expected to be carried out in coordination between system operators.

- RfG sets out the rules that new generators must adhere to connect at the desired voltage level.[6] One of its aims is to increase the integration of renewable electricity production units [17];
- DCC focuses on how demand facilities, connected directly or indirectly through a distribution system, interact with the transmission system. It also clarifies the role of demand response in an

[5] The System Operation guideline integrates the network codes for Operational Planning and Scheduling (OPS), Operational Security (OS) and Load Frequency Control and Reserve (LFCR).

[6] Transmission or distribution.

energy system with an increased proportion of energy from renewable energy sources. DCC applies to transmission-connected demand facilities, transmission-connected distribution facilities, distribution systems and demand units used to provide demand response services, both existing and new [18];

- HVDC does not directly tackle TSO-DSO cooperation. As described in [19], the code "lays down the requirements for grid connections of high-voltage direct current (HVDC) systems and DC-connected power park modules." However, it does state that DSOs impacted by the grid connection should be consulted and take into account any potential impact on their system.

In summary, coordination between system operators (TSOs and DSOs) is needed to make sure requirements, for generators and load, connected at different voltage levels, are respected and aligned.

3.1.2 Network codes related to Operation

The category of Operational codes includes a guideline on System Operation (SO) and a code for Emergency and Restoration (ER). These NCs are highly relevant to the current discussion since they define guidelines concerning rules and responsibilities for coordination and data exchange among system operators.

- SO defines principles related to operational security (e.g. grid monitoring, outage coordination), sketches the prequalification process[7] and provides insights concerning minimum information to be delivered by reserve providing units (e.g. voltage level, connection point, type of active power reserve, maximum reserve capacity,…). This guideline aggregates guidelines on Operational Security (OS), Operational Planning and Scheduling (OPS) and Load Frequency Control and Reserve (LFCR) [20]:
    - The guideline on Operational Security sets requirements and principles for the transmission system applicable to all TSOs, DSOs and significant grid users (SGU)[8] in

[7] Prequalification is defined in the NC LFCR as the process to verify the compliance of a Reserve Providing Unit or a Reserve Providing Group of kind FCR, FRR or RR with the requirements set by the TSO according to principles stipulated in this code.

[8] Significant Grid User means the existing and new Power Generating Facility and Demand Facility deemed by the Transmission System Operator (TSO) as significant because of their impact on the Transmission System in terms of the security of supply including provision of Ancillary Services (source of the definition: the draft Network Code on Operational Security). ENTSO-E Supporting Document for the Network Code on Operational Security of 24 September 2013 2nd Edition Final (p. 154) explains,

normal and alert system state. Note that the requirements for frequency control, voltage control and reactive power management take into account the scenario where a TSO might provide instructions to a relevant DSO. Another subject relevant to highlight is the emphasis towards data exchange. TSOs and DSOs shall cooperate in order to define and agree on effective processes for providing and managing relevant data exchanges between them. Hence, a structural and real-time data exchange between system operators (and SGU) is encouraged.

- The guideline on Operational Planning and Scheduling determines minimum requirements to ensure coherent and coordinated operational planning processes on the synchronous areas applicable to all relevant stakeholders (SGUs, TSOs and DSOs). This NC details the process of operational security analysis of the TSO in D-1 and close to real-time (together with solutions for the affected TSO and DSO areas), outage planning and monitoring of reactive power capacities by the DSOs.

- The guideline on Load Frequency Control and Reserve promotes a closer cooperation across TSOs in Europe, supporting further penetration of RES. It defines the concept of a Reserve Providing Unit as "a single or an aggregation of Power Generation Modules and/or Demand Unit connected to a common Connection Point fulfilling the requirements of FCR, FRR or RR."[9] The guideline provides indications that aggregation should also be allowed across DSO areas. Therefore, it indicates the need for DSOs to collaborate with each other in case they act as aggregator or have aggregators present that can aggregate units across all DSO areas within a TSO control area. It is also stipulated that each DSO shall have the right to set temporary limits at any point in time before reserve activation happens. The imposition of limits should be done in a non-discriminatory and transparent way to all reserve providing units. All these procedures require agreement between system operators.

moreover that Significant Grid Users are those Grid Users whose influence on the Transmission System needs to be taken into account for Operational Security.

[9] Frequency Containment Reserves (FCR), Frequency Restoration Reserves (FRR) and Restoration Reserves (RR).

- ER sets the requirements for technical and organizational measures to be undertaken in case of an incident, to prevent its propagation and to restore the situation in order to avoid an extended disturbance and blackout state. These procedures contain amongst others the design and activation of a system defense plan, as well as disconnection and restoration measures. Different plans and procedures are activated in close cooperation with the DSOs. In addition, high priority is given to information exchange between system operators in emergency, blackout or restoration states. For instance, TSOs shall collect information on measures (restoration and emergency actions[10]) implemented by DSOs so they can be included in the design of the system defense and restoration plans. In addition, islanding operation capabilities and status should be communicated by relevant DSOs to the TSO [21].

The NCs related to operation emphasize the need of cooperation among system operators. An enhanced cooperation is based on sharing relevant information frequently enough to provide an accurate illustration of system dynamics. Knowledge on available resources such as location, maximum output and ramping rate allow for a better operational scenario planning. The exchange of data may help to enhance grid observability and in turn support the creation of an accurate and dynamic picture of the state of the system. However, system operators (TSO and DSOs within a control area) must agree on the format, type, aggregation level, frequency and relevancy of the data to be exchanged.

3.1.3 Network codes related to Market

The Market category includes Capacity Allocation and Congestion Management (CACM), Forward Capacity Allocation (FCA) and Electricity Balancing (EB). CACM and FCA are not relevant to this analysis and will not be further discussed. The NC on EB aims to move Europe towards a competitive and integrated European balancing market [22]. The code lays down common rules for balancing including reserves procurement, activation and settlement.[11] In particular, it determines that TSOs are obliged to participate in a coordinated balancing area by i.e. cross-border netting or exchange of balancing services (FRR and RR). Principles for market design are also mentioned (e.g. marginal pricing). Note that the design of such a balancing market may impact DSOs, especially when balancing services are sourced by DER directly connected to the DSO grid. In conclusion, the code encourages cooperation among relevant stakeholders (i.e. TSO, DSO, balancing service providers and BRPs). Cooperation is spurred by the request

[10] The definition of emergency situations and procedures dealing with such events are out of the scope of the Smartnet project [21].

[11] Procurement and settlement for FCR, FRR and RR. Activation for FRR and RR.

for the creation of a methodology for a fair allocation of costs resulting from the provision of balancing services from the DSO grid. In addition, the code supports information exchange between DSO and TSO with respect to the imbalance settlement.

3.1.4 Conclusion

In conclusion, the implementation and future updates of all NCs are important for TSO-DSO collaboration. It is expected that operational agreements between system operators will be based upon the framework determined in the NCs. As seen, NCs address several important topics such as:

- Assessment of connection requirements for generation and load;
- Exchange of data for grid operation and network planning (observability and control arrangements);
- Emergency procedures;
- Market design for the trade of balancing services also sourced by DER units directly connected to the DSO grid;
- Possibility for DSOs to impose limits to the activation of balancing services coming from the distribution grid;

However, these topics will need to be further detailed, taking also into account the following aspects:

- Country characteristics such as national regulation (current and expected evolution), state of the grid, structure of TSOs and DSOs,...
- Details of data exchange. This needs to be determined jointly by TSOs and DSOs. Relevant elements are the content of the information, the ownership of the information, the frequency of exchange, the confidentiality, the ICT requirements, ….
- Ongoing market developments will have an impact on future updates of regulation. For example, it should be monitored to what extent the development of local markets for ancillary services products is compatible with the requirements determined for ancillary services and markets in the NCs.
- In future revisions of the NCs, the aspect of collaboration and joint responsibilities between system operators will need to be further clarified.

In addition to the topics listed above, ENTSO-E also asks for a joint mandate with DSOs to develop an arena for more formalized cooperation between TSOs and DSOs. This includes relevant areas such as new legislation for distributed flexibility (i.e. demand side response, dynamic pricing, distribution grid management, data exchange,…) [23].

As seen from the summary of the NCs, the discussion is not focused on the need for coordination but rather on how to organize such cooperation. The present deliverable attempts to provide insights that could be used for this purpose. Chapter 3.3 illustrates the current environment concerning flexibility-based services across seven (7) EU countries. Chapter 4 introduces five TSO-DSO coordination schemes.

3.2 Evolutions on roles and responsibilities, system operation and flexibility market design

Several stakeholders have issued position papers addressing changes to be made to the regulatory framework with respect to *roles and responsibilities*, *system operation* and *flexibility market design* in order to enhance the cooperation between TSOs and DSOs [11], [14], [23]–[27]. The key elements are further discussed in section 3.2.1, 3.2.2 and 3.2.3.

3.2.1 Roles and responsibilities

As grid managers, both TSOs and DSOs are responsible for the secure operation of their respective networks, which involves managing congestion and voltage on their grids [26]. However, in a situation with increasing amount of DER, connected at the distribution grid, current roles of system operators are subject to evolution. In particular for the DSO, current roles might be extended and new roles could emerge. Concerning grid operation, DSOs could play an important role as active system managers, technological enablers, data managers and innovators [28]. In addition, DSOs could be involved in the development of local markets as both neutral market facilitator, market officer and contributor to system security [11], [26]. As neutral market facilitator, DSOs support the participation of resources connected to the distribution grid to the flexibility market. The DSO as contributor to system security will support the TSO by providing local solutions for system-wide problems. In the role of market officer, the DSO is able to contract flexibility resources both in long and short term for local purposes (e.g. congestion management). Currently, DSOs are not allowed to contract and/or use flexibility-based services as an alternative to delay or avoid network reinforcements to cope with the increasing intermittent generation [11], [26], [29].

Similar to the rules defined for TSOs, DSOs cannot be on both sides of the market as both market facilitator and service provider. If they are demanding or buying a system service, DSOs and TSOs should not be active as commercial service providers [25], [26].

Not only the roles of system operators are subject to evolution, also the roles and responsibilities of other market parties are impacted by recent market developments. In particular, the role of third parties, responsible for aggregation of small flexibilities, is under discussion. In a number of countries, third party aggregators offer customers the opportunity to engage in demand response. An example of ongoing

debate is the discussion related to standardized contractual frameworks that could define the key operational arrangements between third party aggregators and the customer's BRP/supplier, e.g. defining balance responsibility, adequate data exchange, financial compensation measures and robust methodologies to estimate demand response volumes [28]. In addition, the transparency of the rules for participation to the flexibility market is important [23].

Policy makers will need to acknowledge the strong element of subsidiarity[12] in the evolution of roles and responsibilities for TSOs and DSOs [25]. Due to the large heterogeneity in roles and responsibilities of system operators, there is no one-fits-all solution which could be applicable for every country or balancing area.

3.2.2 System operation

Cooperation between system operators supports optimal system planning and operation. In particular, this calls for intensification of relevant data and information exchanges between system operators. A clear and consistent regulatory framework should be designed by Member States (MS) for data management and fulfillment of the following standard criteria: (i) transparency and a clear definition of the access rights, (ii) cost-efficiency, (iii) high standards of data privacy, (iv) and a high level of reliability [25].

In the different stages of system operation (planning, short-term operation and emergency), the need for more and better data sharing is mainly related to the information exchange on the respective 'observability' area of the DSO and the TSO. The idea is that all system operators should share an overview of the situation of their system in an aggregated way [24]. Building a common understanding of the status of each other's network will be a key facilitator to better managing the growing interactions between networks under different system operators and across all timeframes (including real time) [14].

TSOs should work with DSOs and regulators in determining requirements around observability [25]. In addition, the granularity and transparency of data, expected by policy makers, is increasing, explaining why data gathering and data sharing requires improvement [26]. Demand response will be facilitated and supported if network availability is known at any moment in time [28].

The use of flexibility resources by TSO and DSO requires a high level of coordination. When decisions are made on the TSO side, the impact of these decisions on the DSO side (and vice versa) need to be taken into consideration [26]. In addition, it is important that TSOs, DSOs and aggregators select mutually the

[12] More information on the principle of subsidiarity can be found in [30].

best solutions for solving local constraints, i.e. voltage or congestion problems [26]. In addition, a greater information sharing between TSOs and DSOs could support system operators to identify where one party can and should take action to support the needs of the other and the system as a whole [14].

3.2.3 Flexibility market design

TSOs and DSOs need to provide consumers with access to all markets. All resources (generation, storage and demand) connected to transmission or distribution grids should be able to participate in energy markets and offer services to the system. This will require appropriate market frameworks (e.g. rules for conflict resolution) supported and enforced by TSOs and DSOs [25]. Regulatory arrangements need to create the right signals and the framework to allow the competitive market to address system needs and minimize the efforts needed by the DSO and TSO overall [14].

Flexibility resources can match different needs and could potentially create conflicts dependent on who uses the flexibility and for which purpose [26]. Resources should be allocated based on technical and economic optimization, i.e. flexibility should be used where its potential is the highest [25], [26]. Creating exclusive, fragmented markets per DSO and per TSO will jeopardize this ability for resources to maximize their economic potential [25]. An adequate regulatory framework provides ways to allocate flexibility resources in a smart way so that a social optimum could be reached [11].

In the future, current balancing markets are expected to evolve further. Such evolution should enable (i) trading of services that allow market players to balance their positions at all times; (ii) markets to include operational grid constraints (both at transmission and distribution) under shorter lead times; (iii) flexibility procurement without jeopardizing grid operation or creating extra costs [25]. In addition, more sophisticated products and services should be integrated, implementing timeframes that better fit the flexibility requirements from system operators [28].

3.3 Flexibility-based services: a country survey

A questionnaire on TSO-DSO cooperation was completed for the following countries: Austria, Belgium, Denmark, Finland, Italy, Norway and Spain. The main results are presented in this chapter.

3.3.1 Contracting AS from DER directly connected to the DSO-grid

Ancillary services are used at transmission system level to balance the system and manage energy fluctuations. At distribution system level, services with similar characteristics may be used for the management of local system challenges. At TSO level, these services may be classified into frequency control, voltage control and other ancillary services. In some cases, regulation and technology allow grid units (load or generation resources), connected directly to the distribution grid, to provide e.g. balancing services to the TSO. The same units may also provide local system services to the DSO.

Figure 2 and ***Figure 3*** illustrate the current situation of TSOs and DSOs contracting AS in the surveyed countries. In ***Figure 3*** the countries colored in grey were not included in the survey.

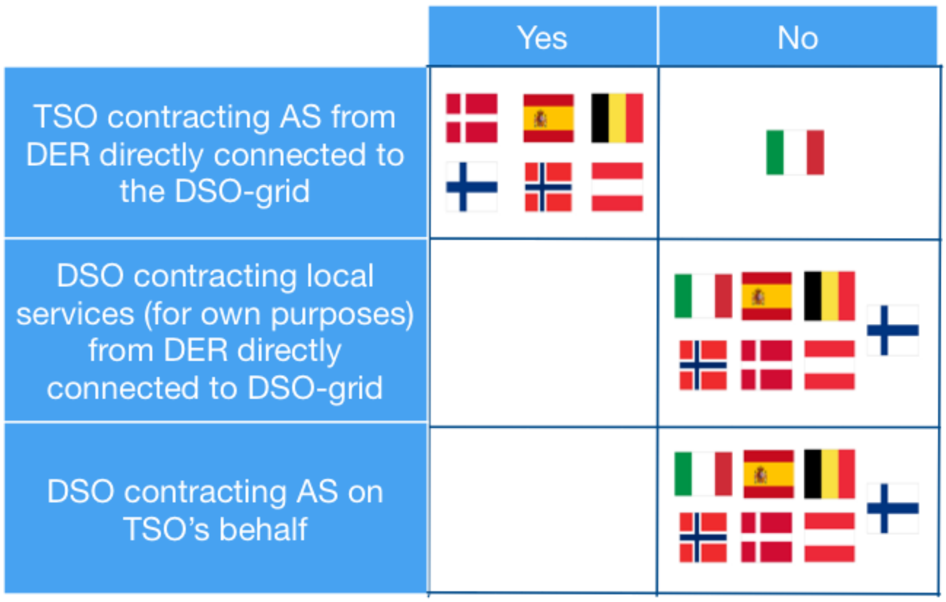

Figure 2 Current status of ancillary services contracting at distribution system level

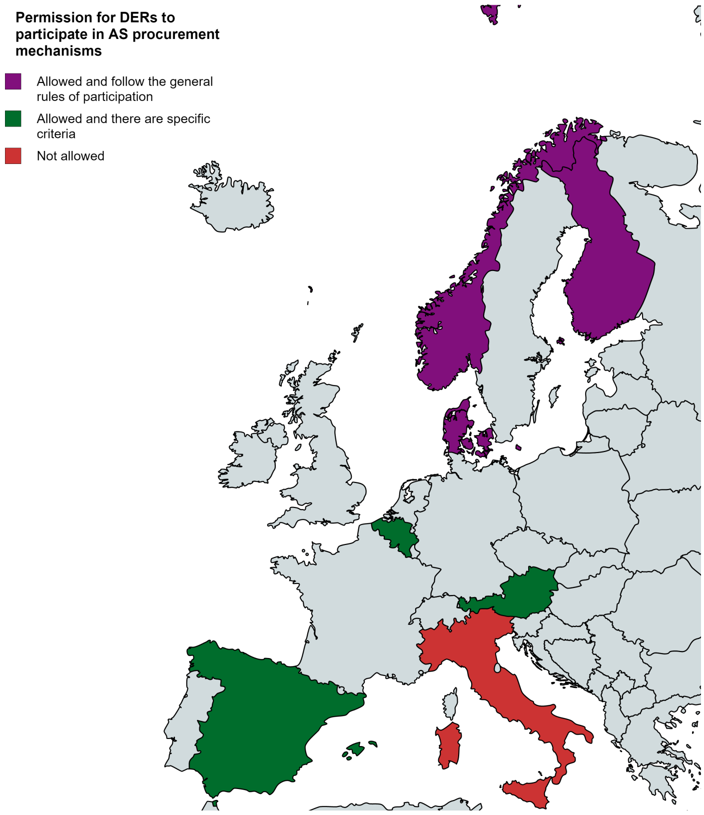

Figure 3 DERs' participation in AS procurement mechanisms

3.3.2 TSO contracting AS from DER directly connected to the DSO-grid

According to the survey, Italy is the only country where DER are not allowed to provide ancillary services. In this way, current rules are constraining the use of flexibility-based services for the Italian system. In all other surveyed countries, DER (Storage, DG and/or DR) are allowed to participate in the procurement mechanisms managed by the TSO. However,

- The minimum rated power and the type of ancillary services where DER are allowed to participate varies among the countries.
- The rules for DER participation vary across European countries.

Dependent on the country, DER are allowed to participate to different types of AS products. There exist quite some differences between countries related to the type of AS product and the procurement mechanism.

Concerning the type of AS product, DER are participating to FCR markets in Austria, Belgium and Finland and to FRR markets in Austria, Belgium, Denmark, Finland and Norway. Other types of AS-participation can be found in Spain where, for example, DER are participating to RR markets or are providing power factor control.

Figure 4 gives an overview of the procurement mechanisms used for each type of ancillary service relevant to DER participation per country. As highlighted in the figure, contracting flexibility-based services from DER directly connected to the distribution grid is commonly done via a market-based procurement mechanism. Mandatory provision is seen only in Spain (e.g. with power factor control).

Figure 4 Procurement mechanisms for AS provided by DER

In general, few limitations exist to the type of DER to participate. If a certain AS product is accessible for DER (i.e. DER is allowed to provide the service), it is almost in all cases relevant for all DER-types.

Today, in most countries, the variety in DER-participation to AS markets is large while the contracted volume is still marginal. However, it is clear that the participation of DER to AS markets is increasing. ***Table 26*** in appendix gives an overview of the AS products where DER are allowed to participate for the countries examined in the survey. For each AS-product, the name, the procurement mechanism and the type of DER allowed to participate are mentioned.

3.3.3 DSO contracting local services from DER directly connected to DSO-grid

As seen in ***Figure 2***, today, all DSOs do not contract flexibility from resources connected at the distribution grid to solve local grid constraints. Similar results for different countries are also confirmed

by the results presented by the EvolvDSO project [2]. The main barrier is related to the permission for the DSOs to contract system services for its own operational purposes (and with this the uncertainty of recovering the cost related to these services). There are only few exceptional cases in which the DSO is allowed to contract system services for his own operational purposes. In Norway and Austria, DSOs may use, in some cases, small-scale hydropower for voltage regulation. This service is acquired not via a market-based mechanism but via connection requirements.

3.3.4 DSO contracting AS on behalf of the TSO

In all of the surveyed countries, DSOs are not allowed to procure AS on behalf of the TSO. This means they cannot act as an aggregator for such purpose. Acting as such would mean to aggregate resources from a local market and transferring the aggregated bids to the central AS market, organized by the TSO. The only exception is a Finnish system pilot case where the TSO requests heating load reduction for lost reserve within the framework of a bilateral contract between the DSO and the TSO.

3.3.5 Information exchange relevant to AS procurement and activation from DER

The exchange of relevant information related to the procurement and activation of AS among concerned market parties, i.e. TSOs, DSOs, aggregators and BRPs, is essential to limit the impact on the operation of the grid (especially at DSO level) and the positions of market players (i.e. creating undesirable imbalances in BRPs' portfolio). Today, the position of aggregators is still unclear. Aggregators are known as a new service provider, responsible for the aggregation of smaller sized flexibility resources. In several countries, aggregators are balance responsible (or manage the responsibility on behalf of someone else), i.e. in Spain, Denmark and Finland. In Belgium, Norway and Austria, aggregators are currently not necessarily BRPs. In Italy, the role of the aggregator is even not recognized and as a result, the activity of aggregation does not yet exist in Italy.

Information exchange during AS procurement and activation serves various purposes for BRPs, TSOs and DSOs.

BRPs may be affected by the activation of AS. To avoid unforeseen system imbalances, BRPs have to exchange information with system operators and if needed, with other BRPs, during both procurement and activation processes. As a result, stakeholders become knowledgeable of potential actions. Hence, responsible parties could be identified and accounted for the impact.

Note that information exchange practices differ from one country to another mainly due to the variation of the role of BRPs and aggregators. For instance,

- In Austria, BRPs get ex-post information about procurement and/or activation of AS in their perimeter: i.e. they are aware of the event after it happens (after flexibility is activated).
- In Finland, the market rules do not require any real time information exchange between a market actor and its BRP. Every actor in the balancing market and AS markets self informs his BRP as agreed with the BRP. This is one of the reasons why electricity market aggregators are in practice either closely connected to their BRP or are themselves BRPs.
- In Norway, the BRP is not informed when the TSO is activating the AS until the balancing settlement is performed.
- In Belgium, BRPs are notified 15 minutes after activation starts. The information exchanged consists of the maximum amount of potentially activated power within its perimeter.
- In the Danish system, all AS are procured and activated through the BRP.

There are settlement mechanisms in place in different countries to deal with the impact of the balancing perimeter of BRPs caused by the activation of ancillary services. For instance,

- In Finland, the system operator, when calculating the settlement, removes the calculated activated response from the balance of the BRP.
- In Belgium, the imbalance settlement mechanism does not consider the impact AS activation might have on the imbalances of BRPs.
- In Denmark and Spain, the imbalance settlement is set in such a way that if a BRP imbalance helps the system i.e. opposite to the direction of the system imbalance, the cost of imbalance is equal to the day-ahead price. Conversely, if a BRP imbalance contributes to the system imbalance, the cost is the marginal balancing price, which is typically 10% higher/lower than the day-ahead price.

While the purpose of TSO-DSO data exchange is broad, it also aims at smoothening operational processes to minimize costs and to maximize efficiency. Among the surveyed countries, however, only in Belgium, TSOs exchange information with the DSOs concerning *prequalification* and *procurement* of ancillary services sourced from DER directly connected to the distribution system. Moreover, dependent on the AS product, the DSO or TSO is responsible for the prequalification procedure. For instance, for the Tertiary reserve product Dynamic Profile (R3DP), the DSO performs a check on the amount of flexible power, technical conformity and the effect of attached generators and loads on the network. In case the DER unit does not pass the prequalification procedure, the DSO is allowed to refuse the connection of the resource, and as a result, the resource is not able to participate to the AS market. In the other surveyed countries, DSOs are not involved in a prequalification process with respect to AS.

In addition, in none of the surveyed countries TSOs exchange information with the DSOs concerning the *activation* of AS from distribution system level. The main reason given is that today, the activation of resources connected at the distribution grid is still limited, so the impact on the DSO grid is also limited, and thus potential problems are not seen as significant. As a result, also confirmed by the survey, there is no clear practice of blocking or modifying activation of AS by the DSO at the distribution system level. The TSO directly activates resources connected at the distribution grid, without notification to the DSO.

DSOs provide measurement data usually through the SCADA system. These measurements are used for the final imbalance settlement. For instance, in the Belgian system, DSOs may also exchange data collected from the meter, network and/or contracts via the Message Implementation Guides (MIG) process under explicit request from eligible parties and explicit consent from relevant grid users. However, Belgian DSOs do not contract system services yet.

3.3.6 Coordination schemes: approaches towards an enhanced cooperation

Today, the cooperation between TSOs and DSOs in the context of the prequalification, procurement, activation and settlement of DER sourced flexibility-based services is limited.

From the survey, it becomes clear that today, the coordination between TSOs and DSOs is mainly focused on discussions around,

- Network planning (i.e. in Austria and Norway);
- The installation of a common data platform (e.g. Atrias initiative in Belgium [31]), or
- Collaboration on the implementation of meters and online measurements (e.g. Denmark).

Although in most countries, DER units are allowed to provide a variety of services for system management, there is currently limited coordination between TSOs and DSOs in the processes involving the use of flexibility coming from the distribution grid. In addition, local markets that trade flexibility-based services sourced by DER units are not a reality (yet). The TSO contracts directly resources connected at the distribution grid, without involvement of the DSO. Moreover, the activation of contracted resources does not seem to be communicated to the DSO. This makes the implementation of an active distribution system management approach a hard task for DSOs. It is obvious that in a scenario with increasing RES and increasing participation of DER to AS markets, the need for closer TSO-DSO coordination will increase and new processes and ways of coordination need to be envisioned. In chapter 4, a selection of these coordination schemes will be further explored.

4 Coordination schemes

As highlighted in chapter 3, the coordination between system operators is gaining importance. In this chapter, five models for TSO-DSO coordination will be presented. Each coordination scheme will determine the operational processes and information exchanges between system operators related to prequalification, procurement, activation and settlement of flexibility-based services that impact both transmission and distribution system level.

In section 4.1, the five coordination schemes are introduced. In section 4.2, the link between the evolution of the roles of system operators and the coordination schemes is further clarified. Section 4.3 deals with the constraints of the distribution grid and the impact of the coordination schemes. In section 4.4, the market design in relation to the coordination schemes is discussed. The chapter concludes with an assessment of different ancillary services in the context of different coordination schemes in section 4.5.

4.1 Overview of coordination schemes

Each coordination scheme is characterized by a set of roles, taken up by TSOs, DSOs and other market players, and a general market design, in line with these roles. The distinction between roles is essential as the increased need for coordination between system operators should not create any confusion in allocating respective roles and responsibilities [14].

A role is defined as an intended behavior of a specific market party which is unique and cannot be shared. Each role has certain responsibilities inherent to the role. A role defines how one market party interacts with another market party during a certain transaction [32].

In this section, five coordination schemes, based on the analysis of chapter 3, are presented in detail.

4.1.1 Centralized AS market model

In this scheme, The TSO contracts DER directly from DER owners connected to the DSO grid for AS purposes. The DSO can procure and use resources to solve local grid issues, but the procurement takes place in other timeframes than the centralized AS market. ***Table 2*** summarizes the market design and main responsibilities for each system operator (i.e. TSO and DSO).

Characteristics	
Market design	There is one common market for ancillary services, operated by the TSO, for both resources connected at transmission and distribution level. There is no separate local market.
TSO role	The TSO is responsible for the operation of its own market for ancillary services. The TSO does not take DSO constraints actively into account. A separate process (system prequalification) could be installed to guarantee that the activation of resources from the distribution grid by the TSO does not cause additional constraints at the DSO-grid (e.g. congestion).
DSO role	The DSO is not involved in the procurement and activation process of AS by the TSO, except in the case that a process of system prequalification[13]is installed to guarantee that the activation of resources from the distribution grid by the TSO does not cause additional constraints at the DSO-grid (e.g. congestion). The DSO is not procuring local flexibilities in real-time or near to real-time.

Table 2 Centralized AS market model

Figure 5 illustrates the role played by relevant stakeholders. Additionally, the figure shows a high-level view of the market architecture and interactions among players.

[13] The general process of prequalification could be divided in two separate processes: technical prequalification and system prequalification). A technical prequalification validates the technical requirements of a unit that wants to participate to the AS market. System prequalification is defined as an up-front process where the DSO validates the participation of DER to the flexibility market, under the condition that it does not violate local grid constraints. More detailed information related to system prequalification can be found in section 4.3.

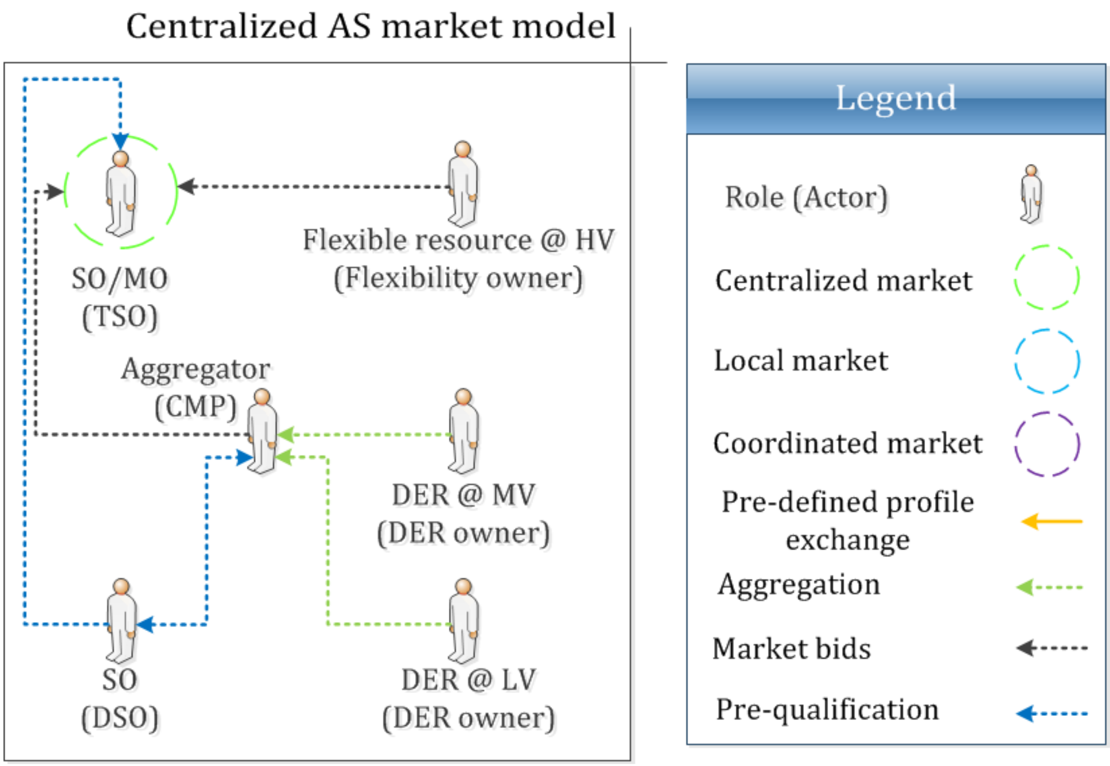

Figure 5 Centralized AS market model: high-level view of roles, market architecture and stakeholder interactions[14]

In summary, this scheme limits the involvement of the DSO to a possible role in the system prequalification process (Figure 5). To note that in exceptional cases, the DSO might want to include DSO grid constraints in the TSO market clearing process. Consequently, the DSO will need to provide the necessary data to the TSO or the TSO should have full observability of the DSO-grid.

4.1.2 Local AS market model

The main principle of this scheme is the operation of a local market by the DSO. The TSO can contract DER indirectly via a local market, after the DSO has aggregated these resources and has transferred them to the TSO AS market. ***Table 3*** summarizes the market design and main responsibilities for each system operator (i.e. TSO and DSO).

[14] The different actors and roles are discussed in detail in section 4.2.1.

Characteristics	
Market design	There is a separate local market managed by the DSO. Resources from the DSO grid can only be offered to the TSO via the DSO/local market and after the DSO has selected resources needed to solve local congestion. The DSO aggregates and transfers bids to the AS market, operated by the TSO. The DSO assures that only bids respecting the DSO grid constraints can take part in the AS market.
Role of TSO	The TSO is responsible for the operation of its own market for ancillary services, where both resources from the transmission grid and resources from the distribution grid (after aggregation by the DSO) can take part.
Role of the DSO	The DSO is the operator of a local market for flexibility. The DSO clears the market, selects the necessary bids for local use and aggregates and transfers the remaining bids to the TSO-market. The DSO has priority to use the flexible resources from the local grid.

Table 3 Local AS market model

Figure 6 illustrates the role played by relevant stakeholders. Additionally, the figure shows a high-level view of the market architecture and interactions among players.

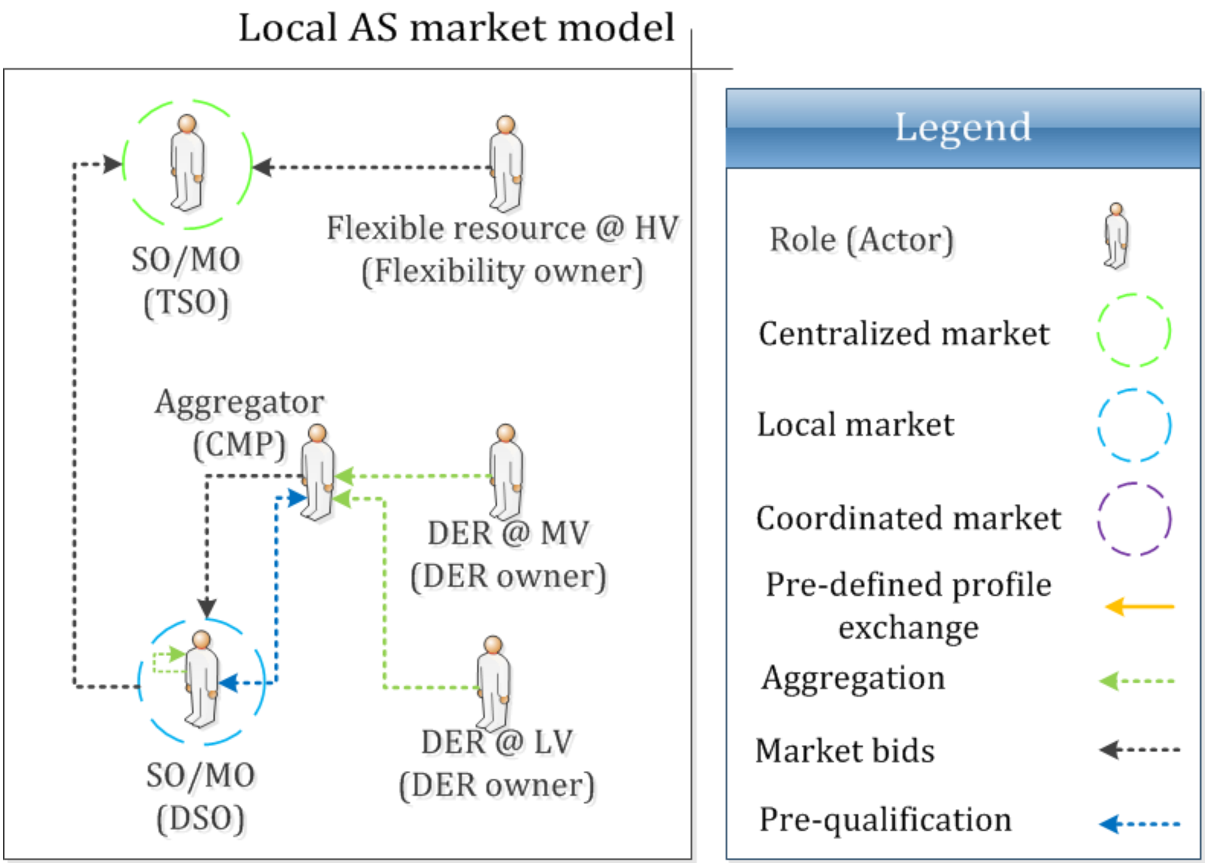

Figure 6 Local AS market model: high-level view of roles, market architecture and stakeholder interactions

In sum, the *Local AS market model* deviates from the *Centralized AS market* model by promoting a local market. The implementation of such a market shifts priorities towards the DSO. All flexibility not needed/procured at the local market (where the DSO is the market operator) is sent to the central market (where the TSO acts as the market operator) in an aggregated form, taking into account that the distribution network constraints are respected (e.g. some local market bids could possibly not be transferred to the TSO if that would jeopardize the distribution grid operation). In this scheme, the DSO contracts and aggregates (already) aggregated bids.

4.1.3 Shared balancing responsibility model

For this scheme, the TSO transfers the "balancing" responsibility for the (local) distribution grid to the DSO. The DSO has to respect a pre-defined schedule[15] and uses local DER (obtained via a local market) to fulfill its balancing responsibilities. The pre-defined schedule is based on the nominations of the BRPs (for the entire DSO-area), possibly in combination with historical forecasts at each TSO-DSO interconnection point. In case the pre-defined schedule is based on the outcome of the energy-only markets, TSOs and DSOs do not make any modifications to this schedule. This means that the pre-defined schedule is determined at the level of the entire DSO-area and not at the level of the TSO-DSO interconnection point, due to the fact that today, nominations are not exclusively made for each TSO-DSO interconnection point. Alternatively, TSOs and DSOs could determine the pre-defined schedule, using historical forecasts for each TSO-DSO interconnection point, together with congestion constraints for both the transmission and distribution grid. In this second option, the pre-defined schedule is determined for each individual TSO-DSO interconnection point. ***Table 4*** summarizes the market design and main responsibilities for each system operator (i.e. TSO and DSO).

Characteristics	
Market design	There is an AS market for resources connected at the TSO-grid, managed by the TSO. There is a separate local market for resources connected at the DSO-grid, managed by the DSO. Resources from the DSO-grid cannot be offered to the TSO-grid. DSO constraints are integrated in the market clearing process of the local market.

[15] The schedule could be a net injection or a net off-take, dependent on the local situation of the DSO-grid.

Role of TSO	The TSO is the operator of the AS market, limited to resources connected at the transmission level. The TSO is responsible for the balancing of the transmission grid.
Role of the DSO	The DSO is the operator of a local market. The DSO contracts local flexibility for both local congestion management and balancing of the DSO-grid. The DSO is responsible for the balancing of the DSO-grid, i.e. respecting the pre-defined schedule.

Table 4 Shared balancing responsibility model

Figure 7 illustrates the role played by relevant stakeholders. Additionally, the figure shows a high-level view of the market architecture and interactions among players.

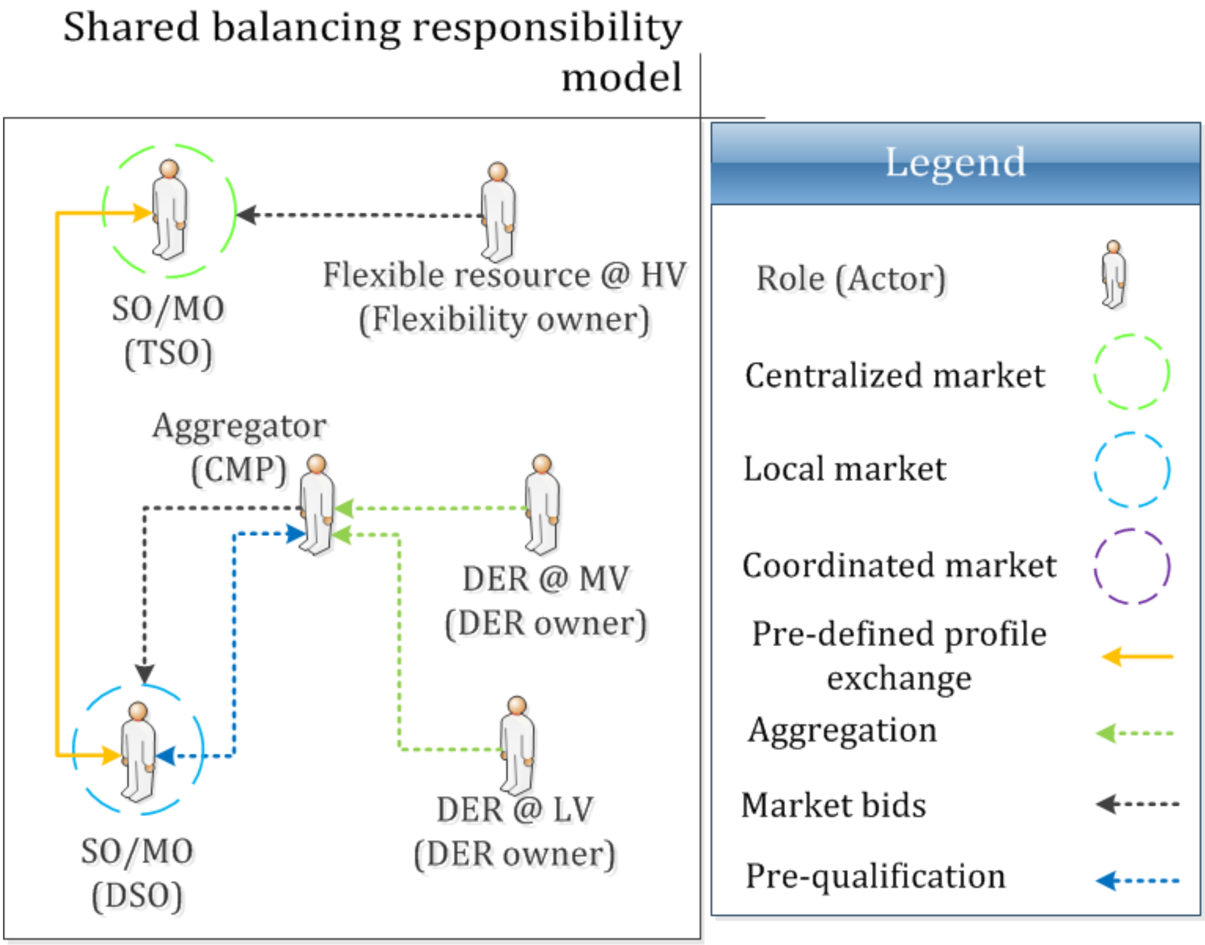

Figure 7 Shared balancing responsibility model: high-level view of roles, market architecture and stakeholder interactions

The *Shared balancing responsibility model* is the only coordination scheme where the TSO has no access to resources connected at the distribution grid. Flexibility from the distribution grid is reserved exclusively for the DSO, in order to fulfill its responsibilities with respect to local grid constraints and local grid balancing.

4.1.4 Common TSO-DSO AS market model

The *Common TSO-DSO AS market model* promotes a common flexibility market for system operators (SO). The procurement of resources made under this coordination scheme has as main goal to minimize total procurement costs of flexibilities. This idea is also supported by the recent position paper issued by CEER which states that it is essential that controls on revenue recovery for DSOs and TSOs create incentives to optimize outcomes for the system as a whole, rather than focusing on minimizing the DSO's and TSO's costs in isolation [14]. ***Table 5*** summarizes the market design and main responsibilities for each system operator (i.e. TSO and DSO).

Characteristics	
Market design	There is a common market for flexibilities for both TSO and DSO with both resources connected at transmission level and connected at distribution level. TSO and DSO are both responsible for the organization and operation of the market. DSO constraints are integrated in the market clearing process. Two alternatives are considered: (1) all constraints are integrated in one only optimization process that encompasses both TSO and DSO grid constraints (centralized variant), (2) a separate local DSO market for local grid constraints runs first (without commitment to the market participants) and communicates with an AS market operated by a TSO with transmission grid connected resources. The outcome of the second market communicates back to the first market to find the optimal solution to be communicated to the market participants (decentralized variant).
Role of TSO	The TSO and DSOs are jointly responsible for the market operation of the common TSO-DSO market (centralized variant) while they are jointly responsible for the final outcome of the two separate market runs (decentralized variant). The TSO is contracting AS services from both transmission and distribution. In practice, in the centralized variant, the joint responsibility could be organized by allocating the responsibility to a third party, under guidance of both TSOs and DSOs.
Role of the DSO	The TSO and DSOs are jointly responsible for the market operation of the common TSO-DSO market (centralized variant) while they are jointly responsible for the final outcome of the two separate market runs (decentralized variant). The DSO uses

	flexible resources from the distribution grid in cooperation and interaction with the TSO.

Table 5 Common TSO-DSO market model

Figure 8 illustrates the role played by relevant stakeholders. Additionally, the figure shows a high-level view of the market architecture and interactions among players.

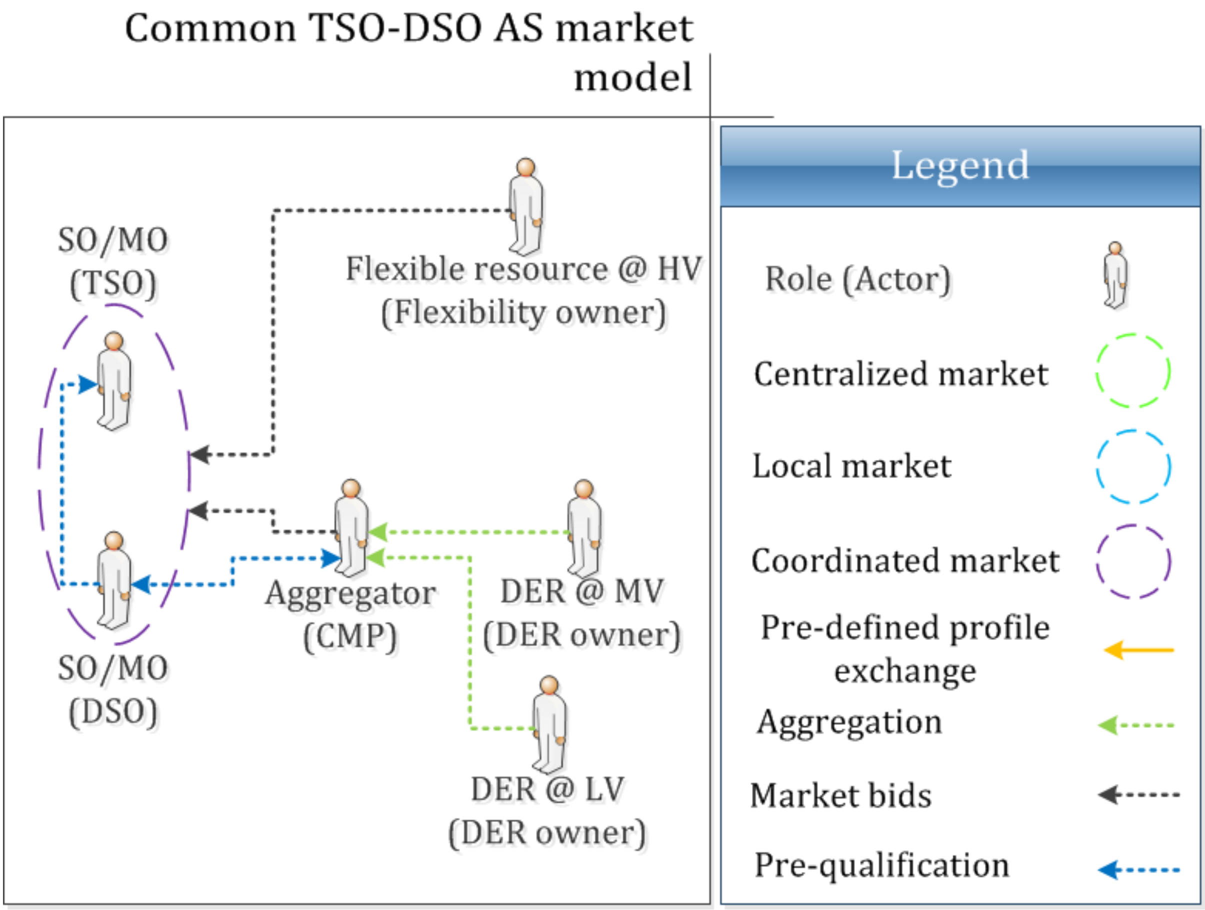

Figure 8 Common TSO-DSO AS market model: high-level view of roles, market architecture and stakeholder interactions

In summary, the *Common TSO-DSO AS market model* could be seen as an extension of the *Centralized AS market model* (for the centralized variant) and the *Local AS market model* (for the decentralized variant). In the centralized variant, the optimization is still organized by aggregating both resources connected at transmission grid and distribution grid, but in this scheme, not only TSO grid constraints are integrated but also DSO grid constraints and possible local needs for flexibility are part of the common market. The decentralized variant differs from the *Local AS market model* in such a way that the DSO has no priority to use flexible resources from the distribution grid. The choice of which resources to be used

by the DSO to solve local constraints will depend on the combined optimization of both needs for flexibility at distribution level and needs for flexibility at transmission level.

4.1.5 Integrated flexibility market model

The *Integrated flexibility market model* promotes the introduction of a market where regulated (TSO and DSO) and commercial market parties (CMPs) procure flexibilities in a common market. ***Table 6*** summarizes the market design and main responsibilities for each system operator (i.e. TSO and DSO).

	Characteristics
Market design	The common market for flexibilities is organized according to a number of discrete auctions and is operated by an independent/neutral market operator. There is no priority for TSO, DSO or CMP. Resources are allocated to the party with the highest willingness to pay. There is no separate local market. DSO constraints are integrated in the market clearing process.
Role of TSO	TSOs are contracting AS services in a common market. TSOs can sell previously contracted DER to the other market participants.
Role of the DSO	DSOs are contracting flexibilities for local purposes in a common market. DSOs can sell previously contracted DER to the other market participants.

Table 6 Integrated flexibility market model

Figure 9 illustrates the role played by relevant stakeholders. Additionally, the figure shows a high-level view of the market architecture and interactions among players.

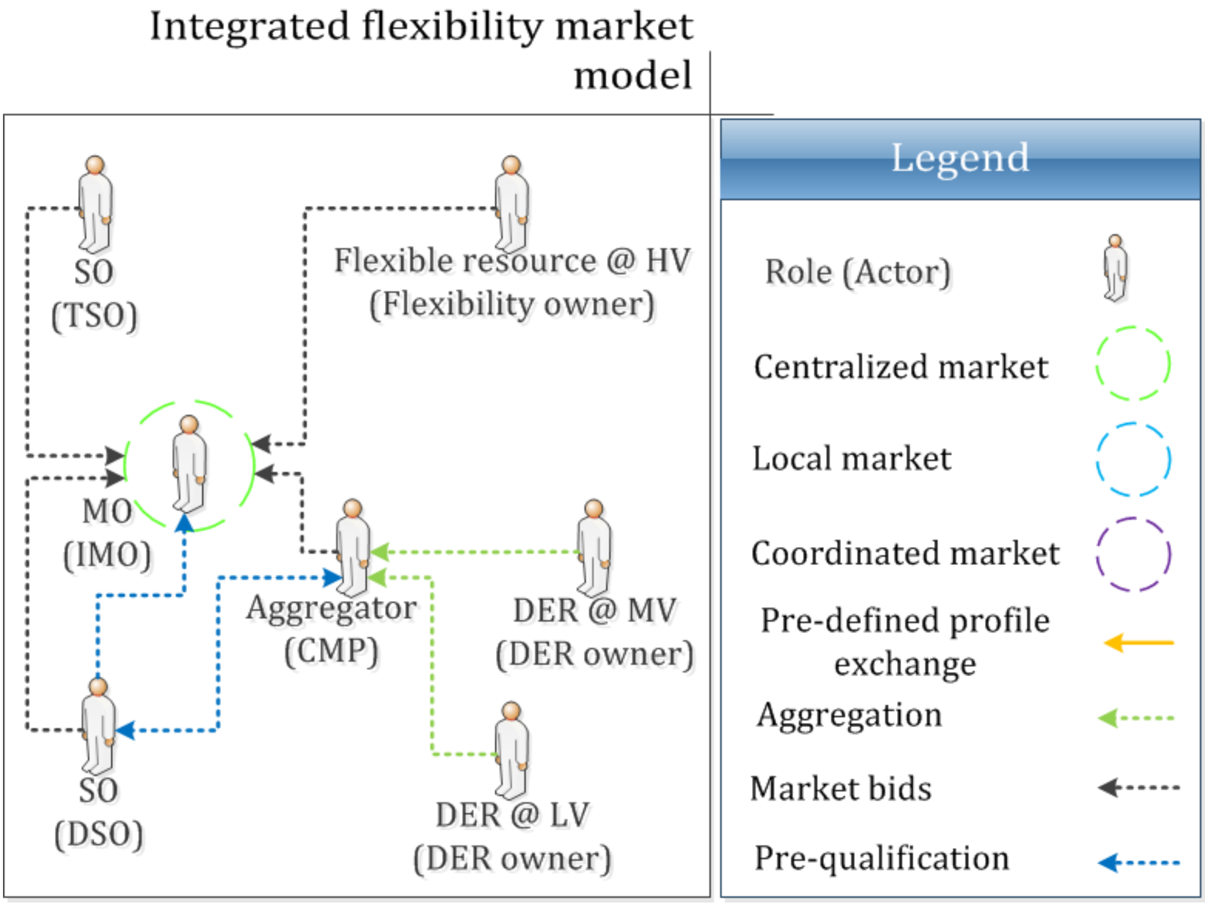

Figure 9 Integrated flexibility market model: high-level view of roles, market architecture and stakeholder interactions

In sum, the *Integrated flexibility market model* proposes a market mechanism where available flexibility can be procured by system operators and commercial market parties under the same conditions. There is no distinction between regulated and liberalized actors. Market forces dictate how flexibility will be allocated. This allocation, however, will respect grid constraints at all voltage levels. Further details on the way grid constraints are integrated in the coordination schemes are presented in section 4.3.

4.2 Coordination schemes and the evolution of system operators roles

System operators fulfill a large set of roles during their daily activities. Each coordination scheme, introduced in section 4.1, requires a different set of roles to be taken up by system operators.

The selection of relevant roles is based on the ENTSO-E role model [10] for the TSO, the EvolvDSO role model [11] for the DSO and some additional roles[16] , specific for the interaction between TSO and DSO.

4.2.1 Overview of roles

Table 7 provides an overview of the most relevant roles that have to be considered in the context of the prequalification, procurement, activation and settlement of ancillary services. For each role, it is indicated which market party could take up this role.

		Role	Explanation	Adopted by
Domain	Grid operation	System Operator (SO)	Operates and manages the physical system in question	TSO; DSO
		System Balance Responsible (SBR)	Ensures the balance of the grid and reduces deviations for a system or certain area by the activation of reserves	TSO; DSO
		Data Manager (DM)	Handles grid data (incl. formatting, storage and provision), separately for each network level.	TSO; DSO; IMO
	Prequalification	Flexibility Feasibility Checker (FFC)	Responsible for assessing potential impact at distribution grid level (system prequalification) caused by the provision of flexibility-based services from a DER unit requesting participation to the AS flexibility market (central or local)	DSO
	Procurement	Reserve Allocator (RA)	Determines the amount of flexibility-based services (e.g. reserves) to be procured	TSO; DSO
		Buyer	Acquirer of flexibility-based services in a market setting	TSO; DSO; CMP
		Seller	Provider of flexibility-based services in a market setting	TSO; DSO; CMP;
		Market Operator (MO)	Responsible for setting up the market platform and operating the market	TSO; DSO; IMO

[16] Additional roles were the result of the in depth analysis of the coordination schemes and the impact on prequalification, procurement, activation and settlement.

		Aggregator[17]	Collector of DER flexibility for its offering in a market setting	DSO; CMP
	Activation	Flexibility Dispatcher (FD)	Activates DER units providing flexibility by sending operational signals	TSO; DSO; IMO; CMP
	Settlement	Metered Data Responsible (MDR)	Responsible for measuring activated energy and for providing relevant related data to the party calculating the settlement	TSO; DSO; CMP

Table 7 Overview of roles

4.2.2 Mapping of roles and coordination schemes

As seen in section 4.1, the roles taken up by system operators differ between coordination schemes. In the *Centralized AS market model*, the role of the DSO is limited and the TSO is the central market party being responsible for almost the entire AS procurement process. In the other coordination schemes, there is a gradual increase of the role of the DSO. In the *Integrated flexibility market model*, an additional market party, the independent market operator, is introduced, taking over some of the roles previously carried out by system operators.

Some roles could be seen as supporting roles and are always taken up by TSOs and DSOs, independent of the coordination scheme. Examples are the role of System Operator, System Balance Responsible and Data Manager. The main task of both TSO and DSO is to guarantee the reliability and safe operation of their grid. In addition, the TSO is the balance responsible for the entire system, which includes both the transmission and the distribution grid. Only in the *Shared balancing responsibility model*, the DSO takes over the balance responsibility for his respective distribution grid. The role of data manager is essential for each step in the process of procurement of AS (and, if allowed by regulation, the procurement of system services by the DSO). Both TSO and DSO are responsible for their own data, which implies that they should organize how they can share data in case they have a common interest. For example, in the *Common TSO-DSO AS market model*, system operators are jointly responsible for the operation of the market, and should share the relevant data to be able to take up this joint responsibility (e.g. location of

[17] The role of aggregator could be both performed by a CMP and a DSO. In the case a CMP or Flexibility Service Provider takes up the role of aggregator, this implies a commercial activity of collecting DER from DER owners at a certain price, which are then further commercialized in different energy markets. In case the DSO takes up the role of aggregator, there is no commercial activity involved. The DSO transfers aggregated offers, submitted in his own local market by commercial parties to the TSO.

the resource, volumes contracted, timing of the activation). In the *Integrated flexibility market model*, the IMO is responsible for the operation of the market platform, using data provided by TSO and DSO. In this case, clear rules for data security and privacy have to be agreed between the IMO and system operators.

An overview of the adopted roles concerning grid operation is illustrated in ***Table 8***.

			Coordination Schemes				
		Role	Centralized AS market model	Local AS market model	Shared balancing responsibility model	Common TSO-DSO AS market model	Integrated flexibility market model
Domain	Grid operation	System Operator (SO)	TSO (Tx)[18] DSO (Dx)[19]	TSO (Tx) DSO (Dx)	TSO (Tx) DSO (Dx)	TSO (Tx) DSO (Dx)	TSO (Tx) DSO (Dx)
		System Balance Responsible (GBR)	TSO (Tx; Dx)	TSO (Tx; Dx)	TSO (Tx) DSO (Dx)	TSO (Tx; Dx)	TSO (Tx; Dx)
		Data Manager (DM)	TSO (Tx) DSO (Dx)	TSO (Tx) DSO (Dx)	TSO (Tx) DSO (Dx)	TSO (Tx) DSO (Dx)	IMO TSO (Tx) DSO (Dx)

Table 8 Grid operation roles adoption across coordination schemes

In each coordination scheme, the DSO will be responsible for system prequalification, i.e. the process where the impact of a certain flexibility source is assessed on the DSO-grid. The technical prequalification, where the technical capabilities of the flexibility source are verified, could be done by a verified independent actor, which should not necessarily be a system operator. A certification from this verified body is than sufficient to make a request for system prequalification.

The DSO is the only entity that can be responsible for system prequalification. As data manager (DM) and system operator (SO) of the distribution grid, the DSO is capable, without third-party intervention, to analyze scenarios and assess potential impacts. Alternatively, if the DSO is not involved in the process of system prequalification, the TSO could perform the assessment on behalf of the DSO, under condition that all relevant data are available and communicated to the TSO. This might be optimal in case of a large number of small DSOs. However, the implications of the latter option would have to be further

[18] Tx = Transmission grid
[19] Dx = Distribution grid

investigated. This in order to avoid potential situations that may impact distribution grid operation costs and dynamics (e.g. non-coordinated actions from TSO and DSO, duplication of data,…).

An overview of the adopted roles concerning prequalification is illustrated in ***Table 9***.

			Coordination schemes				
		Role	Centralized AS market model	Local AS market model	Shared balancing responsibility model	Common TSO-DSO AS market model	Integrated flexibility market model
Domain	Prequalification	Flexibility Feasibility Checker (FFC)	DSO	DSO	DSO	DSO	DSO

Table 9 Prequalification roles adoption across coordination schemes

The role of buyer and seller of flexibility-based services, provided by DER, changes across coordination schemes.

In the *Centralized AS market model*, only the TSO is actively buying resources in short-term (day-ahead, intraday and real-time). The DSO is not buying flexibility-based services in the same timeframe as the TSO. However, the DSO might buy some flexibility resources in the longer term to solve e.g. structural grid congestion or to postpone certain grid reinforcements.

In the *Local AS market model*, the *Shared balancing responsibility model*, the *Common TSO-DSO AS market model*, and the *Integrated flexibility market model*, both TSO and DSO are buying flexibility-based services provided by resources directly connected to the distribution grid in the same time frame. In the *Local AS market model*, resources from the distribution grid are allocated with priority to the DSO while in the *Common TSO-DSO AS market model*, the allocation of resources is based on a global minimization of the costs for concerned system operators. In the *Shared balancing responsibility model*, the TSO has no access to resources connected at the distribution grid, only the DSO can use these resources. In the *Integrated flexibility market model*, commercial market parties are also allowed to compete on an equal base with the regulated parties.

In most coordination schemes, commercial market parties (CMPs) are the sole sellers of flexibility resources. Only in the *Integrated flexibility market model*, system operators could, via the independent market platform, resell back to the market previously contracted flexibility. This could be done to increase liquidity and reduce grid costs.

In none of the coordination schemes, CMPs can make a trade-off between different flexibility markets, i.e. the location of a certain flexibility resource, in combination with the chosen coordination scheme, determines where the CMP could offer the flexibility. This means that for example in the *Local AS market model*, CMPs can only offer flexibility to the TSO, via the local market operated by the DSO. Also in the *Shared balancing responsibility model*, CMPs cannot offer flexibility, connected at the distribution grid, to the TSO.

The role of market operator is directly linked with the market design and is different for each coordination scheme. In the *Centralized AS market model*, the TSO operates both the AS market for resources connected at the distribution grid and for resources connected at the transmission grid. In the *Local AS market model* and the *Shared balancing responsibility model*, TSO and DSO are each responsible for the respective operation of the flexibility market of their grid. In the *Common TSO-DSO AS market model*, dependent on the market design, TSO and DSO operate together one common platform, or alternatively, operate each their respective markets, optimizing the outcome of both markets in mutual agreement. In the *Integrated flexibility market model*, the IMO takes over the role of market operator to guarantee neutrality as commercial market players are now competing with regulated entities.

The aggregation of flexibility resources is done by flexibility service providers or aggregators. Small individual DER are combined and offered in an aggregated way to the market. In addition, it is also possible for the DSO to aggregate individual bids, offered to the local market, and to send them to the TSO in an aggregated form, taking into account specific constraints from the DSO-grid. By doing this, the DSO guarantees that the bids coming from the DSO-grid and used by the TSO, respect all DSO grid constraints. The DSO carries out this activity of DSO-aggregation in the *Local AS market model* and the *Common TSO-DSO AS market model (*decentralized variant). In the former, the DSO aggregates after the resources needed to solve local constraints are taken out. In the latter, the DSO performs the aggregation, using all resources offered to the local market, combined in such a way that local constraints are not only respected but also solved, independent of the selection of bids made by the TSO.

An overview of the adopted roles concerning procurement is illustrated in ***Table 10***.

Domain		Coordination schemes				
	Role	Centralized AS market model	Local AS market model	Shared balancing responsibility model	Common TSO-DSO AS market model	Integrated flexibility market model
Procurement	Reserve Allocator (RA)	TSO (Tx; Dx)	TSO (Tx) DSO (Dx)	TSO (Tx) DSO (Dx)	TSO (Tx) DSO (Dx)	TSO (Tx) DSO (Dx)
Procurement	Buyer	TSO (Tx; Dx)	TSO (Tx; Dx) DSO (Dx)	TSO (Tx) DSO (Dx)	TSO (Tx; Dx) DSO (Dx)	TSO (Tx; Dx) DSO (Dx) CMP (Tx; Dx)
Procurement	Seller	CMP (Tx; Dx)	CMP (Tx; Dx)	CMP (Tx; Dx)	CMP (Tx; Dx)	CMP (Tx; Dx) TSO (Tx; Dx) DSO (Dx)
Procurement	Market Operator (MO)	TSO (Tx; Dx)	TSO (Tx) DSO (Dx)	TSO (Tx) DSO (Dx)	TSO (Tx; Dx) DSO (Tx; Dx)	IMO (Tx; Dx)
Procurement	Aggregator	CMP (Tx; Dx)	CMP (Tx; Dx) DSO (Dx)	CMP (Tx; Dx)	CMP (Tx; Dx) DSO (Dx)	CMP (Tx; Dx)

Table 10 Procurement roles adoption across coordination schemes

After the clearing of the market, the most adequate resources are selected and can be activated. In the case of a capacity market, the buyer has received a capacity and should explicitly send an additional activation signal to the market operator, in case the buyer needs to activate the resource. In the situation of an energy only market, the activation is implicit in the confirmation of the bid (i.e. market clearing), given by the market operator. The activation involves a cascading process, starting with a signal sent from the market operator to the relevant CMP (seller of contracted flexibility). Next, the CMP sends an activation signal to the DER unit(s) required for service provision.

An overview of the adopted roles concerning activation is illustrated in ***Table 11***.

		Role	Coordination schemes				
			Centralized AS market model	Local AS market model	Shared balancing responsibility model	Common TSO-DSO AS market model	Integrated flexibility market model
Domain	Activation	Flexibility Dispatcher (FD)	TSO, CMP (Tx; Dx)	DSO (Dx); TSO (Tx; Dx), CMP (Tx; Dx)	TSO (Tx); DSO (Dx); CMP (Tx; Dx)	TSO (Tx; Dx), DSO (Dx); CMP (Tx; Dx)	IMO and TSO (Tx; Dx), DSO (Dx); CMP (Tx; Dx)

Table 11 Activation roles adoption across coordination schemes

The responsibility for the meter readings to verify the activation could go done by the DSO, via the official DSO-meter or alternatively, in case approved by regulation, via an independent commercial player with an independent meter, only meant for measuring the activation of a flexibility resource.

An overview of the adopted roles concerning settlement is illustrated in ***Table 12***.

		Role	Coordination schemes				
			Centralized AS market model	Local AS market model	Shared balancing responsibility model	Common TSO-DSO AS market model	Integrated flexibility market model
Domain	Settlement	Metered Data Responsible (MDR)	TSO (Tx) DSO (Dx) CMP (Tx; Dx)	TSO (Tx) DSO (Dx) CMP (Tx; Dx)	TSO (Tx) DSO (Dx) CMP (Tx; Dx)	TSO (Tx) DSO (Dx) CMP (Tx; Dx)	TSO (Tx) DSO (Dx) CMP (Tx; Dx)

Table 12 Settlement roles adoption across coordination schemes

4.2.3 The future roles of system operators: feedback consultation

The consultation organized in the context of this report (appendix 8.2) asked specific questions related to the evolution of roles and responsibilities of system operators. The main results are summarized below (see detailed results in appendix 8.3).

All respondents confirm that, although increased coordination between system operators is needed, it should be clear that TSOs should be responsible for the transmission grid and DSOs remain responsible for the distribution grid. This implies that DSOs will be responsible for local constraints management.

Several additional roles for the DSO were discussed in the consultation: the role of the DSO as local market operator, the role of the DSO as balance responsible for the distribution grid and the role of the DSO as buyer of flexibility. The role of local market operator by the DSO is considered as a possibility by several respondents, similar to the current responsibility of the TSO as market operator of current AS markets. However, other respondents raise important attention points with respect to neutrality and transparency. In order to guarantee a neutral and transparent functioning of the market, the option of an independent market operator could be considered.

With respect to the question on the possible role of the DSO as balance responsible, most respondents agree that this is probably not a cost efficient solution and that balance responsibility should be organized at a system level by the TSO. In particular, it should be avoided that by splitting up the balance responsibility, inefficiencies are created that might increase grid costs that will be charged to end consumers, i.e. duplication of dispatching centers, costly procurement of resources,…. Due to the fact that the DSO has access to a more limited set of resources, compared to the TSO, the cost of balancing might increase, leading to a sub-optimal solution from a system wide perspective. In addition, splitting up the responsibility for balancing is going against the European trend of increased integration of balancing markets. However, some respondents see also benefits in case the DSO becomes balance responsible, e.g. faster reaction on large imbalances, induced by very local situations.

The procurement of flexibility by DSOs in the short term as an alternative for grid investments is considered as very realistic by all respondents, under the condition that regulation provides the appropriate framework, including proper cost remuneration for the use of flexibility. Also, DSOs will need to adopt a new way of working with dynamic real-time operational security assessments.

One respondent also highlighted the need for system operators to resell previous contracted flexibility back to the market.

4.3 Coordination schemes and the constraints of the Distribution grid

The use of flexibility from DER, connected at the DSO-grid, may have an impact on the grid imposing constraints to its operation. For instance, the activation of DER might violate voltage limits and/or overload distribution lines (leading to an increase in losses). It is therefore important to assess how DSO grid constraints should be integrated in the processes of procurement and activation of ancillary services in order to safeguard security of supply and quality of service. DSO constraints may be taken into account according to four (4) scenarios:

- **Scenario 1**: DSO constraints are not considered. This is currently the case in most European countries and it is also confirmed by the results of the country survey, discussed in section 3.3. It is clear that this is a scenario that could only be acceptable in case the share of resources connected from the distribution grid is below a certain threshold. This threshold may vary across MS and should take into account the state of the grid. Also in distribution grids that are heavily over- dimensioned, it could be agreed that it is not necessary to involve the DSO in any of the processes where the TSO contracts resources from the distribution grid.

- **Scenario 2**: The DSO is involved in a process of system prequalification. During this process, DER assets are analyzed and approval is given by the DSO to the DER owner to participate to the flexibility market. The process of system prequalification differs from a more technical prequalification. During the process of technical prequalification, the technical requirements of a certain resource are assessed to make it eligible to deliver a specific service. During the process of system prequalification, the DSO assesses the impact of the delivery of a specific service by a certain resource on the grid. In case the delivery of the service in that specific area would violate grid constraints, the DSO could forbid the delivery of the service by that specific resource.

- **Scenario 3**: The DSO is not only involved during system prequalification (before procurement), but also after the clearing of the market. The DSO has the possibility to block the activation of a flexible resource (if selected by the clearing of the market), in case DSO constraints might be violated. Blocking a specific resource is a manual and iterative process. The market operator (in case it is not the DSO) will inform the DSO about the market results, the DSO will make an internal assessment and approves or blocks the selected resources. In case of blocking of certain resources, the market is cleared again and the updated results are again sent to the DSO. It is clear that this manual check of DSO constraints might be operationally heavy as it could require multiple iterations within a very short time frame in case constraints of the distribution grid in a specific market are easily violated.

- **Scenario 4**: The DSO is not only involved during prequalification (before procurement), but DSO constraints are also integrated in the market clearing algorithm. This assures that the outcome of the market clearing will not violate DSO grid constraints. The advantage of this scenario

compared to scenario 3 is that it is operationally much easier as no manual actions from the DSO are required after market clearing and no iterations are needed. Nevertheless, integrating physical grid constraints in the market algorithm might be heavy from a mathematical point of view. Also, this requires that the DSO provides the necessary data to the party responsible for the operation of the market. In case the DSO is the market operator, this is trivial, however, in case an external party operates the market, concerns related to privacy and confidentiality of data might need to be addressed.

The first scenario where DSO constraints are not taken into account, illustrates the current situation in most countries. As it can be seen, this scenario does not encourage the implementation of an active distribution system management. Moreover, it is only relevant for very specific conditions. This scenario will not be discussed in detail for the coordination schemes because such scenario does not require any interaction between TSO and DSO.

In case the DSO is the operator of a local market, which is the case in the *Local AS market model*, the *Shared balancing responsibility model* and the *Common TSO-DSO AS market model*, it is logic that DSO constraints are always taken into account in an automated way. This is operationally less heavy and privacy and confidentiality of data are guaranteed.

In a market set-up where the DSO is not the operator of the market, which is the case in the *Centralized AS market model* and the *Integrated flexibility market model*, the choice between different scenarios depends on several aspects such as the state of the distribution grid, the requirements for data protection and confidentiality, the national organization of DSOs,… in order to determine which is the most optimal set-up. In the case of the *Centralized AS market model*, DSOs are only to a limited level involved in the processes for flexibility procurement and activation, carried out by the TSO. As a result, DSO involvement will be mostly limited to system prequalification. However, in some cases, DSOs might want to include DSO grid constraints automatically in the TSO market clearing. Therefore, DSOs will need to provide the necessary data to the TSO or alternatively, should allow the TSO to access directly certain DSO data.

In the *Integrated flexibility market model,* the market is operated by an independent market operator. This IMO could be responsible for the 'blocking' of certain bids, in order to guarantee neutrality. This is in particular relevant for the *Integrated flexibility market model* as DSOs are allowed to resell previously contracted DER. If DSOs are simultaneously a seller themselves and responsible for the acceptance of new sellers in the market (prequalification) and the acceptance of selected bids, this could create potential conflicts of interest. It is important that processes are in place to ensure appropriate justification and transparency around restrictive actions taken by the DSO or TSO [14].

The process of system prequalification is not always necessary in case DSO grid constraints are integrated in the clearing process in a manual or automated way. This could possibly result in a higher participation of DER to the market, but also a higher probability of bids not selected during or after the market clearing.

The advantage of the process of system prequalification is that it gives an indication to flexibility providers in case they might be located in a constrained area. It is important to highlight that the process of system prequalification should also be a dynamic process. It should give the right incentives to DSOs to invest in certain areas to unlock the potential of flexibility. As a result, a request for system prequalification, in case of a negative result, could be repeated after a certain period of time. ***Table 13*** summarizes the main benefits and risks of a specific choice for handling DSO grid constraints.

	Benefits	Risks
Scenario 1 (distribution constraints not considered)	• No additional cost	• Constraints might not be respected
Scenario 2 (DSO involved in system prequalification)	• Implementation costs might be low • DSO grid constraints are taken into account • Provides more information to the DSO (enhancing grid observability)	• Constraints might not be respected • Need for accurate forecasts of future grid load • In order to secure the grid, safety margins taken by the DSO might be very conservative
Scenario 3 (DSO also involved after market clearing)	• DSO grid constraints are always respected • Provides more information to the DSO (enhancing grid observability) • Mathematically not difficult to implement	• Heavy operational process (manual and iterative) • Deadline of finishing the market clearing process might be endangered by this process • Could create uncertainty in the market as it is unclear on which base DSOs might block activations • Issues with transparency
Scenario 4 (Constraints integrated in market clearing)	• DSO grid constraints are always respected • Provides more information to the DSO (enhancing grid observability) • Operational process is relatively light • No issues related to 'neutrality' of the DSO	• Heavy mathematical process to integrate all constraints in the clearing • Need for sharing data between DSO and market operator (discussions on security and privacy of data)

Table 13 Benefits and risks across scenarios

In case no DSO constraints are taken into account, flexible resources could be aggregated across several DSO areas without any problems. In case DSO grid constraints should be taken into account, aggregation of bids across several areas might need to reflect the locality aspect of the bid. Market products will need to decide if this means that aggregation will only happen at the level of the individual node or if aggregation could still happen over a larger area. In the second case, there could be e.g. market products that will only be partially cleared (dependent on the locality) in case of violation of constraints.

4.4 Coordination schemes and market design

Each of the coordination schemes is characterized by a specific market design. In this section, the *scope of the market*, the *organization of the market*, and the *operation of the market* are highlighted and discussed.

4.4.1 Scope of the market

The scope of the market analyzes which types of resources are participating to it, taking into account the location of these resources.

In the *Centralized AS market model*, the *Common TSO-DSO market model* (centralized variant) and the *Integrated flexibility market model*, both resources connected at transmission and distribution level are participating in the same market session. In the *Local AS market model*, the *Shared balancing responsibility model* and the *Common TSO-DSO market model* (decentralized variant), resources connected at the distribution level are offered and optimized in a separate market session. In case there is one market platform, there is the need for only one market operator. In case of different markets, multiple market operators might co-exist.

4.4.2 Organization of the market

The market for ancillary services could be organized according to a set of discrete auctions or as a continuous market. In case a market is organized as a continuous market, the advantage is that at any moment in time, there might be the possibility to trade, till gate closure. The argument of more frequent trading options becomes less relevant in case the frequency of the discrete auctions is increased. On the contrary, a disadvantage of a continuous market is that there might be a risk of low liquidity. The same disadvantage appears for discrete auction markets with a high auction frequency.

In addition, in the case of the *Integrated flexibility market model*, not only regulated but also non-regulated players are participating to the market. In a continuous market structure, the price setting is according to the pay-as-bid concept and there might be the risk that the TSO and DSO are paying a much higher price, compared to a market organized with discrete auctions (and marginal pricing). Other market players could wait till the last moment to place their bids, while the TSO is obliged to buy reasonably in advance to guarantee system stability. Market players will know this, asking a higher price, above their marginal cost, for deals done further away from gate closure.

Another disadvantage of a continuous market set-up would be the fact that it is almost impossible to integrate DSO grid constraints as this should imply a continuous check of grid constraints every time a bid is submitted. Of course, in case local grid constraints should not be checked continuously, a

continuous market is possible as well. In addition, it is clear that in case the market is a continuous market, this organization is fairly similar to the set-up of current intraday markets. For more information on the possible link with the intraday market, see section 5.2.3.

Hence, for a market of AS services, from a conceptual point of view, it seems best to organize it by a set of discrete auctions, making a trade-off between a higher liquidity on the one hand and a frequency of auctions which is high enough to give flexibility to the participants of the market. In all of the coordination schemes, the market design assumes discrete auctions.

4.4.3 Operation of the market

The market could be operated by the system operators or by an independent market operator (IMO). In the coordination schemes where there is a single buyer, i.e. one system operator that has exclusivity to buy resources from one specific market, this single buyer is also responsible for the operation of his own market (similar to current practices for procurement of AS by TSOs in many countries). This is the case for the *Centralized AS market model*, the *Local AS market model*, the *Shared balancing responsibility model* and the *Common TSO-DSO AS market model* (decentralized variant).

In coordination schemes where multiple system operators (*Common TSO-DSO AS market* – centralized variant) or both regulated and non-regulated parties participate (*Integrated flexibility market model*), the operation of the market should guarantee neutrality, transparency and a high level of operational efficiency. In this case, an independent market operator could be responsible for the operation of the market.

In the *Common TSO-DSO AS market model*, TSOs and DSOs could still be the main and only shareholders of this independent entity. It seems logic to assume that, in case TSOs and DSOs are jointly responsible for the operation of the market, for efficiency reasons, an independent entity is necessary, especially in the case that multiple TSOs or DSOs are participating.

For the *Integrated flexibility market model*, the presence of an IMO is a precondition to assure a fair level playing field where no distinction is made between regulated and non-regulated entities.

4.4.4 Future market design: feedback from the consultation

General elements are mentioned by several respondents about the main characteristics of a proper market design (appendix 8.2). The market design should:

- Allocate flexibility in the most efficient way
- Minimize gaming and unfortunate price effects
- Ensure sufficient liquidity
- Be transparent
- Support competition
- Respect grid constraints
- Stimulate participation to the market for both buyers and sellers of flexibility
- Assure that system operators do not activate flexibility resources that are in conflict with actions done by the other system operator

The consultation highlights a clear preference for a more centralized market organization to guarantee liquidity, efficiency in market operation and standardized products and processes. As a result, this could even be a facilitator for the participation of small DER to the market for ancillary services. One remark was given that, when combining both constraints of transmission and distribution in one single market place, the optimization problem might become highly complex and potentially not feasible to solve in an adequate time frame.

Most respondents highlight several issues that might arise in case several local markets are organized. Liquidity in small local markets might be small and DSOs will not have the possibility to access flexibility located in a different DSO-area in case this is needed for balancing purposes. Another element of attention is that the smaller the market size, the higher the risk for market power and high prices. Several respondents explicitly mention that fragmentation of markets should be avoided as much as possible.

Although consensus exists on how the market should be organized, diverging opinions are expressed on who should have access to this central market place as a buyer of flexibility. A small number of respondents prefer this market to be only accessible for the TSO, other respondents see this market as a common market for all system operators. A majority of respondents would prefer that both system operators and commercial companies compete in the same market environment to buy flexibility, under the condition that local grid constraints are respected.

Also in terms of priority, no consensus exists. Some respondents prefer a clear priority for the TSO to guarantee system security at all times. Others emphasize the need for priority for the DSO, due to the fact that at a local level, few options might exist for the DSO. In this case, clear rules should be determined in which situations the DSO should have priority. Other respondents do not want to assign any upfront priority to any system operator. On the contrary, they want market forces to determine where the use of a

specific flexibility, in case, multiple parties are interested in the resource, has the highest economic value. Several respondents highlight the importance that in the end, the decision taken should lead to lower costs for end consumers.

4.5 The organization of ancillary services under different coordination schemes

The different coordination schemes are analyzed for a selection of ancillary services. The processes of **prequalification**, **procurement**, **activation** and **settlement** are analyzed and described in each use case[20], in order to assess the impact of a specific coordination scheme.

The following three ancillary services are considered:

1. Use of flexibility from the distribution grid by the TSO for **frequency restoration/balancing** (aFRR, mFRR and RR) and **congestion management**[21] at the level of the transmission grid. In addition, the link with the use of flexibility (i.e. system flexibility services) from the distribution grid by the DSO for local purposes (e.g. local congestion management) was analyzed;
2. Use of flexibility from the distribution grid by the TSO for **frequency control** (FCR);
3. Use of flexibility from the distribution grid by the TSO to support **voltage control** of the transmission grid.

Other ancillary services are not further considered. Further description of these services can be found in [12], [20].

It is expected that, by 2030, these services will not be mature or will not be procured in a market based environment [12]. However, the conclusions made for the ancillary services listed above in terms of interaction between system operators and the related information exchange, could be extended to other ancillary services. The consultation organized for this report also asked respondents to give feedback with respect to the selected use cases. All respondents emphasize the importance of the use case related to balancing and congestion management, due to the relevancy for all system operators and as a consequence, the need for coordination. This use case is also considered as the most complex use case, due to the interactions between several market parties. In addition, the use case on the provision of

[20] Within SmartNet a use case is defined as "the provision of a service, within the framework of a certain coordination scheme, from one actor to another actor".

[21] Assumption: characteristics of resources used for frequency restoration and congestion management by the TSO are intrinsically the same, so in the use cases, procurement of these resources can be combined. Note that for some specific countries, structural weaknesses in the transmission-grid might require a temporary and specific procedure for procurement of resources for congestion management separately. Assumption is made that this procurement procedure will be based on bilateral contracts and is outside the general market setting.

frequency control is also seen as very relevant, especially from the perspective of the TSO. The use case on the provision of voltage control to the transmission grid is seen as less crucial.

In addition, several respondents highlight the importance of future research on the use of flexibility from the distribution grid for local voltage control.

In section 4.5.1, the ancillary services presented above are mapped against the different coordination schemes. Next, the impact of a specific coordination scheme is discussed for each ancillary service.

4.5.1 Mapping of coordination schemes and Ancillary Services

Due to the nature of the use cases, not every coordination scheme is feasible or relevant. ***Table 14*** shows a mapping between ancillary services and relevant coordination schemes.

	Ancillary services (AS)			
		Balancing & congestion management		
	Frequency control	aFRR	mFRR & RR	Voltage control
Centralized AS market model	+	+	+	−
Local AS market model	−	+	+	+
Shared balancing responsibility model	−	+	+	+
Common TSO-DSO AS market model	+	+	+	+
Integrated flexibility market model	−	+	+	−

Table 14 Mapping of ancillary services and coordination schemes

The decision if a coordination scheme is applicable to a certain ancillary service is based on the question if the characteristics of the ancillary service are serving the needs of certain market parties.

For balancing and congestion management, all coordination schemes are possible. However, for frequency control and voltage control, some coordination schemes are excluded. The *Integrated flexibility market model* allows both regulated and non-regulated market parties to buy in the same market environment. It is clear that this coordination scheme is only relevant for those ancillary services that have characteristics that satisfy both the needs of a sufficient large range of regulated and commercial market parties. As a result, frequency control and voltage control are very specific and only used by system operators. Therefore, the *Integrated flexibility market model* is not applicable for these use cases.

In addition, frequency control is the unique responsibility of the TSO. Therefore, nor DSOs, nor commercial market parties have an interest to buy this product. It is therefore not likely that the DSO would organize a separate local market for this service. Therefore, only the coordination schemes where the TSO is directly involved in the operation of the market are relevant, i.e. the *Centralized AS market model* and the *Common TSO-DSO AS market model*.

Voltage issues and associated control needs are very location specific and it seems not feasible that a market would exist without involvement of the DSO. In case the DSO would not be in the loop, the TSO would not be able to really control the voltage at the TSO-DSO connection point by steering himself directly assets in the distribution grid. Hence, the *Central AS market model* is not applicable in the context of voltage control.

An important remark is the fact that different ancillary services could be procured via different coordination schemes. This also implies that the procurement of one ancillary service has an impact on the available capacity of other ancillary services.

In the next sections, coordination schemes are applied to the different AS, highlighting differences in roles and market design.

4.5.2 Frequency restoration and congestion management

As discussed in section 4.5.1, resources that could be used both by TSO (for frequency restoration (balancing) and congestion management) and by DSO (for local congestion management) could be organized according to five (5) coordination schemes.

As highlighted in section 4.2.2, the DSO is always responsible for system prequalification. This process is similar across all coordination schemes. Since all prequalification requests pass through the market, the process varies if a local market exists in parallel to the central market. Before a request for system prequalification can be made, a technical prequalification of the resource happens to check the conformity of the technical characteristics of the resource. This technical prequalification can be done by a certified body and is a prerequisite for a request for system prequalification. Figure 10 and Figure 11 show the process of prequalification, both technical and system prequalification. System prequalification

is defined as an up-front process where the DSO validates the participation of DER to the flexibility market, under the condition that it does not violate local grid constraints. More detailed information related to system prequalification can be found in section 4.3. Figure 10 shows the process for a centralized market organization (*Centralized AS market model*, *Common TSO-DSO AS market model – centralized* and the *Integrated flexibility market model*) and Figure 11 shows the process for a decentralized market organization (*Local AS market model*, *Shared balancing responsibility model* and the *Common TSO-DSO AS market model – decentralized*). ***Table 15*** lists actors and actions taken within this process. Steps are applicable to both situations (i.e. central market and local market). Note that the role of certified body (CB) could be performed by a third party. This certification relates to the technical prequalification (see chapter 4.2.2). Also note that the role of MO differs across coordination schemes. This is indicated with an (*).

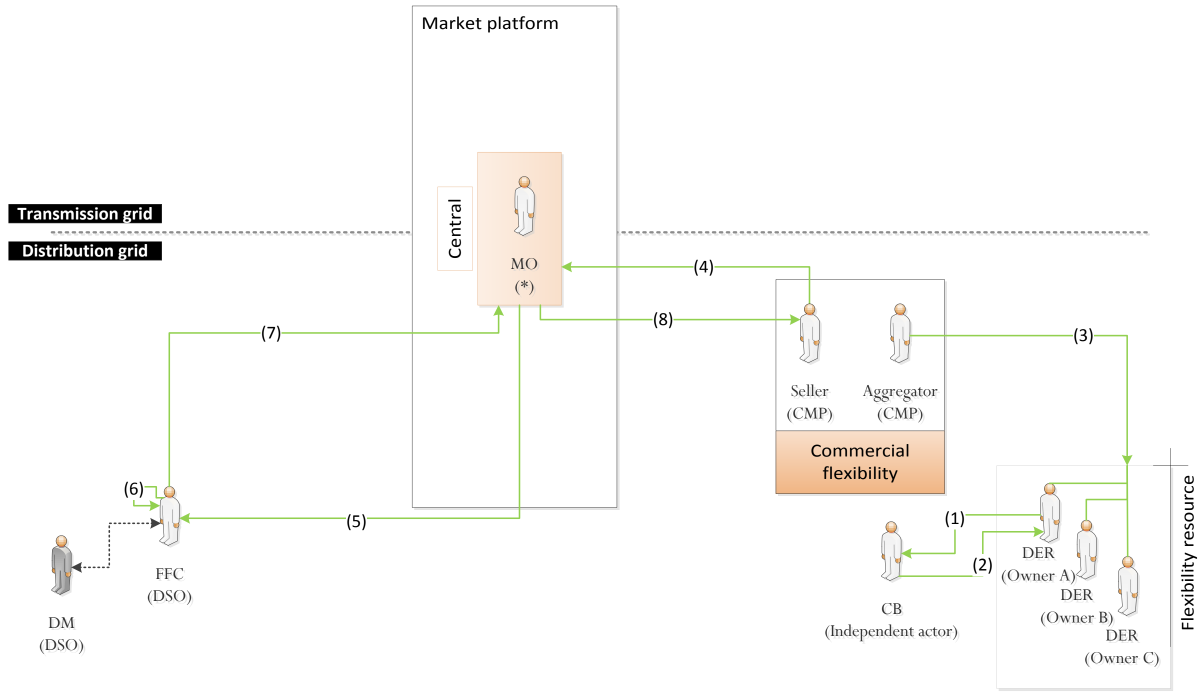

Figure 10 Prequalification process applicable to coordination schemes with a centralized market design[22]

22 (*) the actor adopting the role of market operator (MO) varies according to the coordination scheme.

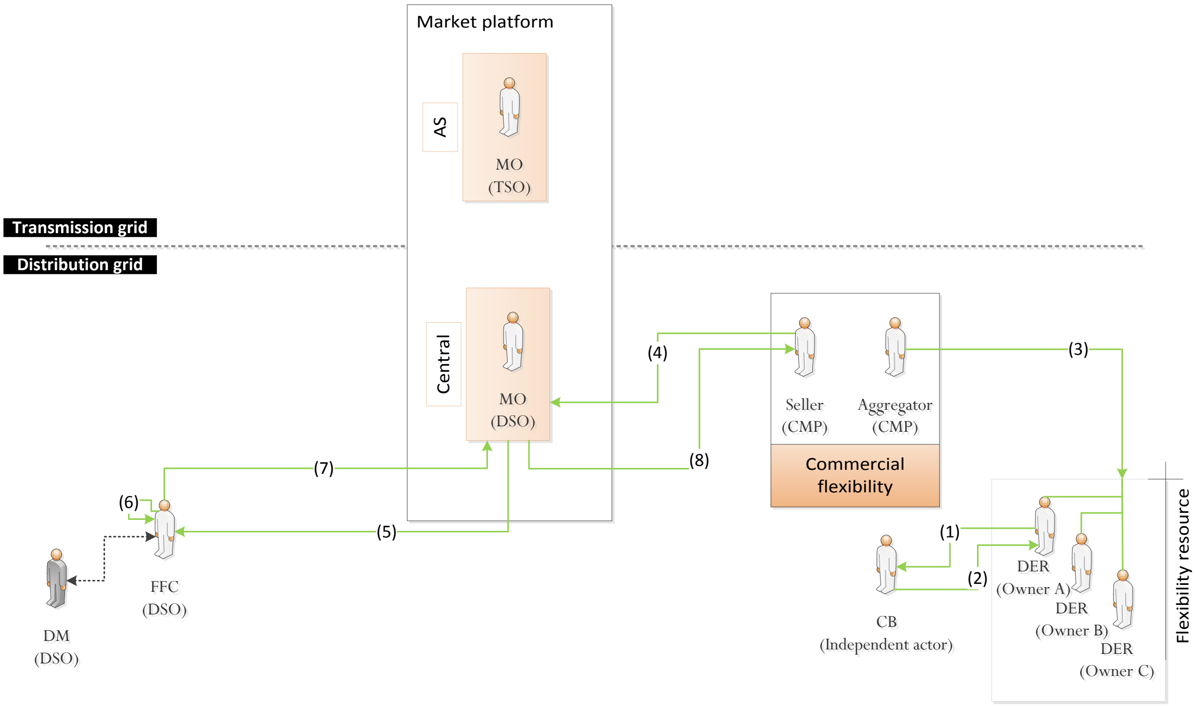

Figure 11 Prequalification process applicable to coordination schemes with a decentralized market design

Steps (#)	Origin	Action	Recipient
1	DER owner	Requests technical prequalification	Certified Body (CB)
2	Certified Body (CB)	Verifies technical characteristics DER and validates technical prequalification	DER owner
3	Aggregator (CMP)	Aggregates DER	DER owner
4	Seller (CMP)	Request system prequalification to market operator	MO (*)
5	MO (*)	Communicates request for system prequalification	FFC (DSO)
6	FFC (DSO)	Assesses impact of DER on local system constraints (limits/capabilities)	
7	FFC (DSO)	Sends response (system prequalification assessment) to	MO (*)
8	MO (*)	Sends response (system prequalification assessment) to	Seller (CMP)

Table 15 Steps within the prequalification process

For the processes of procurement, activation and settlement, main differences between coordination schemes can be found in the procurement process and are linked with the organization and optimization of the market for resources connected at the distribution grid. Figure 12 illustrates the processes for procurement, activation and settlement for coordination schemes *Centralized AS market model*, *Common TSO-DSO AS market model* (centralized) and *Integrated flexibility market model*. ***Table 16*** lists actors and actions taken within these processes. Steps are applicable to the three coordination schemes. Note that the role of market operator (MO) could be performed by the TSO (*Centralized AS market model*), by both system operators (*Common TSO-DSO AS market model* – centralized variant), or by an independent market operator (*Integrated flexibility market model*). Differences across coordination schemes are mainly reflected by the actions linked with the procurement of AS. This is due to the fact that this process is most impacted by changes in the market design, roles adopted and type of information exchanged. The processes of activation and settlement are very similar due to the fact that the main roles, responsible for these activities, are indisputable assigned to specific market parties.

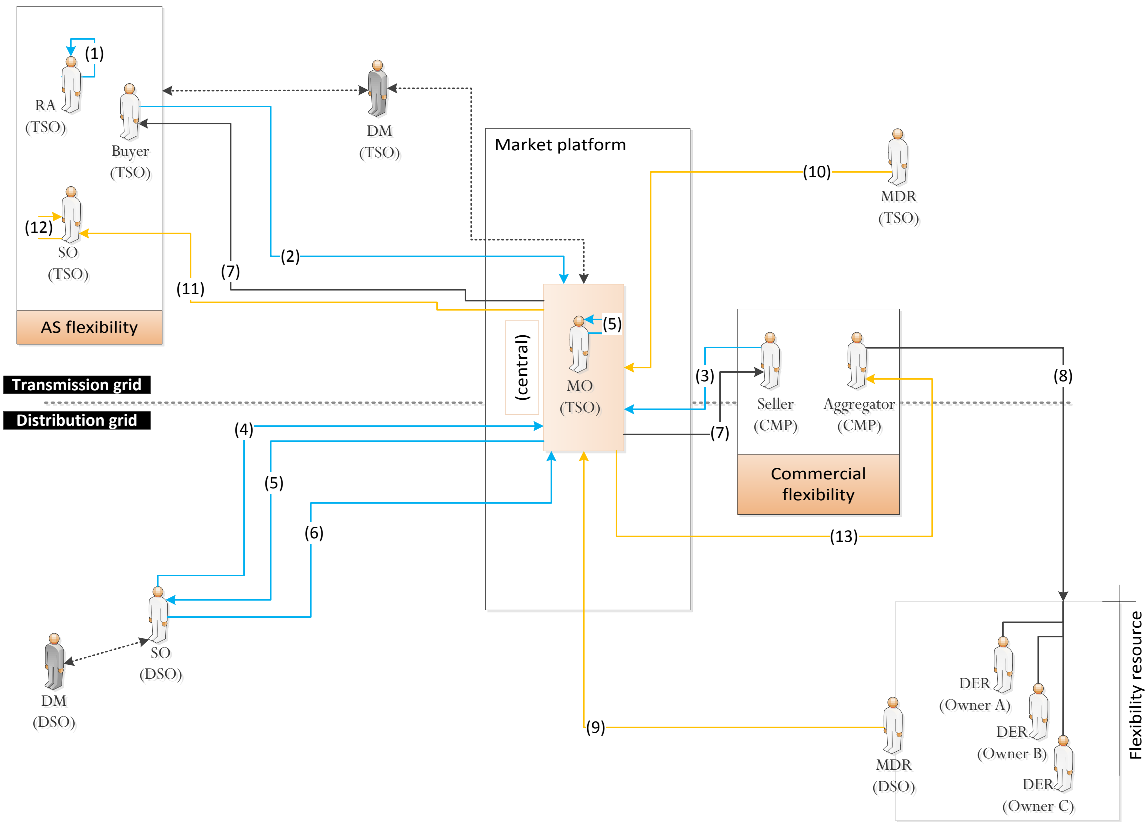

Figure 12 Procurement, activation and settlement for Centralized AS market model,23

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23 (*) the actor adopting the role varies according to the coordination scheme.

	Steps (#)	Origin	Action	Recipient
Procurement	1	RA (TSO)	Determines volumes to be procured	
	2	Buyer (TSO)	Communicates volumes to	MO (TSO)
	3	Seller (CMP)	Sends aggregated bids (from transmission and distribution) to	MO (TSO)
	4	SO (DSO) (*)	Communicates distribution grid constraints to	MO (TSO)
	5	MO (TSO)	Clears market and communicates results to	SO (DSO)
	6	SO (DSO) (**)	Checks if local constraints allow for activation requested by TSO and blocks if needed – communication to MO and step 5 will be repeated	MO (TSO)
Activation	7	MO/FD (TSO)	Communicates results to (activation is simultaneous if no capacity is procured)	Buyer (TSO) Seller (CMP)
	8	Aggregator/FD (CMP)	Activates units based on the selected bids	DER
Settlement	9	MDR (DSO)	Communicates measurements to	MO (TSO)
	10	MDR (TSO)	Communicates measurements to	MO (TSO)
	11	MO (TSO)	Communicates measurements to	SO (TSO)
	12	SO (TSO)	Corrects perimeter of BRPs affected by activation	
	13	MO (TSO)	Performs financial settlement of flexibility activation for resources connected at distribution and transmission grid	Aggregator (CMP)

Table 16 Steps within the procurement, activation and settlement processes for the Centralized AS market model

For a correct interpretation of ***Table 16*** the following should be considered:

- (*) Step 4 should only be considered in case of scenario 4 of the integration of distribution grid constraints (see section 4.3).
- (**) Step 5 and step 6 should only be considered in case of scenario 3 of the integration of distribution grid constraints (see section 4.3).

The steps as explained in ***Table 16*** for the *Centralized AS market model*, could be easily adapted for the *Common TSO-DSO AS market model* (centralized) and the *Integrated flexibility market model*. Differences are related to the operator of the market and the buyers and sellers on the market.

In the *Centralized AS market model*, the role of MO is given to the TSO, while in the *Common TSO-DSO AS market model* (centralized), the role of MO is performed jointly by TSO and DSO and in the *Integrated flexibility market model*, the MO is the Independent Market Operator. This has an impact on all the steps that involve the MO (i.e. steps 2, 3, 4, 5, 6, 7, 9, 10, 11, 13).

In the *Centralized AS market model*, the TSO is the only buyer, while in the *Common TSO-DSO AS market model* (centralized) and the *Integrated flexibility market model*, both TSO and DSO are buyer. This has an impact on all steps related to the purchase of flexibility services (i.e. steps 1, 2 and7).

In the *Centralized AS market model*, only CMPs are seller of flexibility, similar to the *Common TSO-DSO AS market model* (centralized). However, in the *Integrated flexibility market model*, the TSO and DSO are also a seller of flexibility. This has an impact on all steps related to the sale of flexibility services (step 3).

Figure 13 illustrates the processes for procurement, activation and settlement for coordination schemes *Local AS market model* and *Common TSO-DSO AS market model* (decentralized). As before, differences across coordination schemes are not reflected in the actions (which do not change across coordination schemes) but, rather in the market design, roles adopted and type of information exchanged.

Table 17 lists actors and actions taken within these processes. Steps are applicable to both coordination schemes. Note that the role of local market operator (MO) could only be performed by the DSO. In the *Common TSO-DSO AS market model* (decentralized) both MOs contract flexibility that proves beneficial to the system as a whole. From the list of steps it can be seen that actions concerning activation suffer no change (compared with the actions in ***Table 16***).

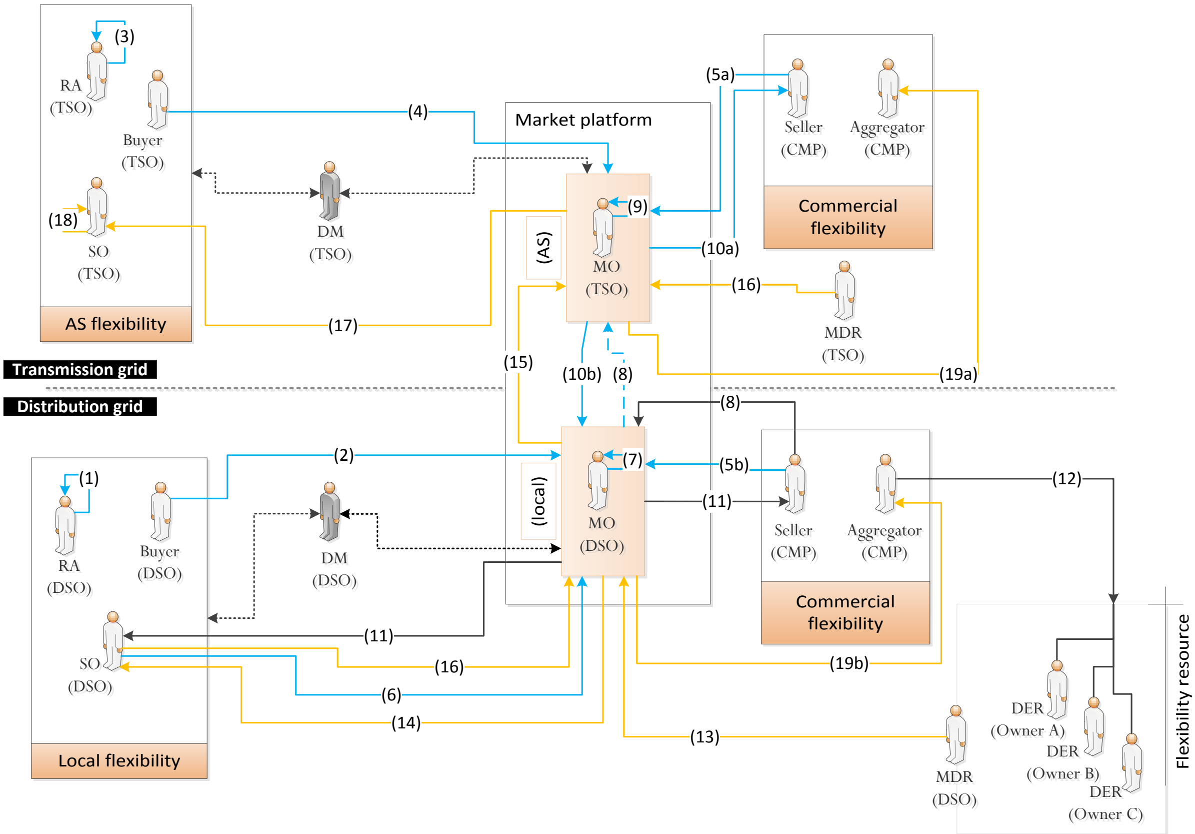

Figure 13 Procurement, activation and settlement for the Local AS market model

	Steps (#)	Origin	Action	Recepient
Procurement	1	RA (DSO)	Calculates volumes of local flex to be procured via the local market for local use	
	2	Buyer (DSO)	Communicates volumes to	MO (DSO)
	3	RA (TSO)	Calculates volumes to be procured at system level	
	4	Buyer (TSO)	Communicates volumes to	MO (TSO)
	5a	Seller (CMP)	Sends aggregated bids of flexibility connected at the transmission grid to AS market	MO (TSO)

	5b	Seller (CMP)	Sends aggregated bids of flexibility connected at the distribution grid to local market	MO (DSO)
	6	SO (DSO)	Communicates distribution grid constraints to	MO (DSO)
	7	MO (DSO)	Clears local market, respecting the local constraints	
	8	MO/Aggregator (DSO)	Aggregates non- selected bids and sends them to the central market	MO (TSO)
	9	MO (TSO)	Clears central market	
	10a	MO (TSO)	Communicates cleared central bids to	Seller (CMP)
	10b	MO (TSO)	Communicates cleared local bids to	MO/Aggregator (DSO)
Activation	11	MO/Aggregator/FD (DSO)	Communicates market results to (activation is simultaneous if no capacity is procured)	Seller (CMP) SO (DSO)
	12	Aggregator/FD (CMP)	Activates selected bids	DER
Settlement	13	MDR (DSO)	Communicates measurements to	MO (DSO)
	14	MO (DSO)	Communicates measurements to	SO (DSO)
	15	MO (DSO)	Communicates measurements to	MO (TSO)
	16	MDR (TSO)	Communicates measurements to	MO (TSO)
	17	MO (TSO)	Communicates measurements to	SO (TSO)
	18	SO (TSO)	Corrects perimeter of BRPs affected by activation	
	19a	MO (TSO)	Performs financial settlement of flexibility activation from resources connected at transmission grid	Aggregator (CMP)
	19b	MO (DSO)	Performs financial settlement of flexibility activation from resources connected at distribution grid	Aggregator (CMP)

Table 17 Steps within the procurement, activation and settlement for the Local AS market model

The steps for the *Common TSO-DSO AS market model* (decentralized) are almost equal to the steps of the *Local AS market model*. The main difference could be found in step 7 and 8. In the Common TSO-DSO AS market model, step 7 is not performed (i.e. the DSO does not clear the market). Instead, step 8 is enlarged: the DSO aggregates all bids into one (perhaps a few) bid(s) (prices and volumes) by taking into

account the distribution grid constraints and, what differs with the *Local AS market model*, by solving the local problems in the bid construction itself. The TSO will clear the central market and decide which bids to choose from the DSO. Dependent on the choice of the TSO, the DSO will activate local resources that solve both constraints of the TSO and the DSO.

Figure 14 illustrates the processes for procurement, activation and settlement for coordination scheme *Shared balancing responsibility model*. ***Table 18*** lists actors and actions taken within these processes. From the list of steps it can be seen that actions concerning activation suffer no change (compared with the actions in ***Table 16***).

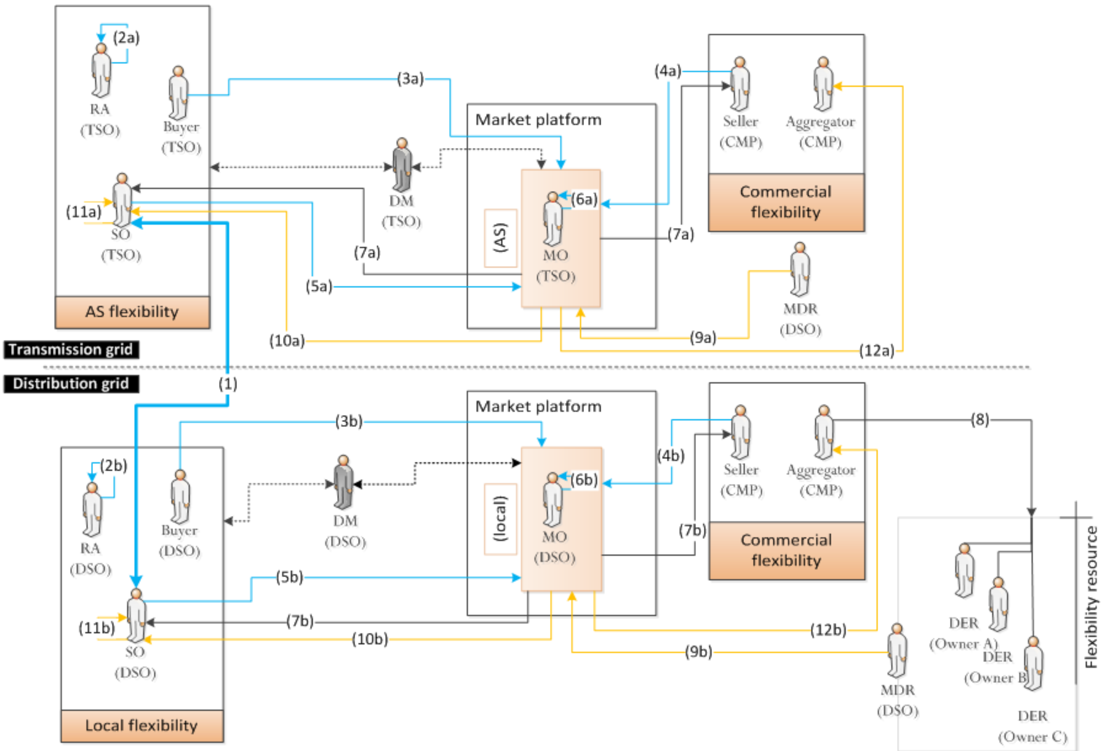

Figure 14 Procurement, activation and settlement for coordination scheme Shared balancing responsibility model

	Steps (#)	Origin	Action	Recipient
Procurement	1	SO (DSO) SO (TSO)	Agrees on exchange profile (mutual agreement)	SO (TSO) SO (DSO)
	2a	RA	Calculates reserve needs to be procured via the	

		(TSO)	central market	
	2b	RA (DSO)	Calculates volumes of local flex to be procured via the local market for local use	
	3a	Buyer (TSO)	Communicates volumes to	MO (TSO)
	3b	Buyer (DSO)	Communicates volumes to	MO (DSO)
	4a	Seller (CMP)	Sends aggregated bids from resources connected at the transmission grid to the central market	MO (TSO)
	4b	Seller (CMP)	Sends aggregated bids from resources connected at the distribution grid to the local market	MO (DSO)
	5a	SO (TSO)	Communicates transmission grid constraints to the central market	MO (TSO)
	5b	SO (DSO)	Communicates distribution grid constraints to the local market	MO (DSO)
	6a	MO (TSO)	Clears market to fulfill SO (TSO) requirements	
	6b	MO (DSO)	Clears market to fulfill SO (DSO) requirements	
Activation	7a	MO/FD (TSO)	communicates central market results to (includes local and system flexibility) (activation is simultaneous if no capacity is procured)	Seller (CMP) SO (TSO)
	7b	MO/FD (DSO)	Communicates local market results to	Seller (CMP) SO (DSO)
	8	Aggregator/FD (CMP)	Activates selected bids	DER
Settlement	9a	MDR (TSO)	Communicates measurements to	MO (TSO)

	9b	MDR (DSO)	Communicates measurements to	MO (DSO)
	10a	MO (TSO)	Communicates measurements to	SO (TSO)
	10b	MO (DSO)	Communicates measurements to	SO (DSO)
	11a	SO (TSO)	Corrects perimeter of BRPs affected by activation of resources connected at the transmission grid	
	11b	SO (DSO)	Corrects perimeter of BRPs affected by activation of resources connected at the distribution grid	
	12a	MO (TSO)	Performs financial settlement of flexibility activation of resources connected at the transmission grid	Aggregator (CMP)
	12b	MO (DSO)	Performs financial settlement of flexibility activation of resources connected at the distribution grid	Aggregator (CMP)

Table 18 Steps within the procurement, activation and settlement for coordination scheme Shared balancing responsibility model

The choice of the coordination scheme does not only determine the responsibilities of system operators towards each other, but determines the responsibilities towards third parties as well. Several of these responsibilities, such as system prequalification, are independent from the coordination scheme. However, some of the responsibilities, i.e. the correction of the BRP perimeter after activation, are linked with the chosen coordination scheme. In the *Shared balancing responsibility model* the DSO is responsible for balancing the local grid and hence, will be responsible for the correction of the BRP perimeter, while in the other coordination schemes, this responsibility is assigned to the TSO.

4.5.3 Frequency control

Frequency Containment Reserves (FCR) are reserves that are used to maintain the frequency of the grid. They are activated autonomously by local measurements. Thus FCRs do not need any data communication for activation (beside the system frequency as a reference). They are also called primary reserves, because they are the fastest reacting reserves and are first activated during disturbances. FCRs constantly regulate the fundamental frequency of the AC-power system.

As discussed in section 4.5.1, frequency control is a service where the TSO is the only interested buyer. This means that there will be no unique local market organized and operated by the DSO for these kinds of services. The relevant coordination schemes are the *Centralized AS market model* and the *Common TSO-DSO AS market model* (centralized variant).

Note that for services, outside the scope of normal operation, i.e. emergency situations, other coordination schemes could be also appropriate. For example, the *Shared balancing responsibility model* could be the appropriate model in case the DSO would provide black start or island operation capabilities.

In the *Centralized AS market model*, the role of the DSO is limited to allowing the TSO to use resources from the distribution grid while guaranteeing that DSO grid constraints are not violated. The market for frequency control is a capacity market. This means that DSO grid constraints will be first verified during a process of system prequalification. During the process of system prequalification, the DSO could allow or prohibit the participation of a resource to the market. In a next phase, the process of system prequalification could be refined. The DSO could, for example, determine the range of droop control settings, i.e. the reaction of the flexible resource, dependent on an external signal. These droop control settings could be optimized based on the local grid situation and the total system needs. Note that, dependent on the market situation, it might be cost efficient, not to include the DSO in this process at all, also not explicitly taking into account DSO grid constraints, in case there are never (or almost never) violated grid constraints. There is no real-time control of DSO grid constraints as the activation of FCR is based on local autonomous control in all coordination schemes. Obviously, general grid monitoring controls the state of the grid and might indicate potential real-time constraints.

In the *Common TSO-DSO AS market model* (centralized variant), the organization of the prequalification, procurement, activation and settlement of FCR is very similar to the *Centralized AS market model*. However, the difference lies in how droop control parameters are adapted. In the *Centralized AS market model*, these parameters are determined once (with or without involvement of the DSO). In the *Common TSO-DSO AS market model* (centralized variant), due to the close cooperation between system operators, these parameters are determined on a regular base (could be on a daily basis, but even a lower granularity, i.e. hours or minutes before activation could be envisioned) and hence, could integrate in a more dynamic way the day-to-day constraints of the distribution grid. As a result, DSOs could be less strict in the phase of system prequalification, allowing more resources to participate to the FCR market. The setting of droop control parameters is the most critical part in terms of communication requirements between TSO and DSO in the context of FCR.

4.5.4 Voltage control

The voltage control ancillary service (AS) is used to provide the reactive power (Q) available by DSOs and DER, connected at the transmission network, beyond their minimum mandatory band (in case there is a minimum mandatory band). The support of resources connected at the distribution grid to support the voltage at the transmission grid is a very particular service. The service is delivered at the interconnection point between TSO and DSO. As explained in section 4.5.1, the relevant coordination schemes are the *Local AS market model*, the *Shared balancing responsibility model* and the *Common TSO-DSO AS market model*.

In the *Local AS market model*, the DSO offers reactive power to the TSO, but the TSO has its own market where he will choose between the offer of the DSO and alternative offers, coming from resources connected at transmission level. If the offer of the DSO is selected, the TSO will inform the DSO.

In the *Shared balancing responsibility model*, the TSO sets a predefined schedule (set-point) to the DSO to be met at the common border node. The DSO uses the flexibility of local DER, obtained via local market, to fulfil its responsibilities on behalf of the TSO. The definition of the set point could be done in mutual agreement between TSO and DSO or could be determined by the TSO only.

In the *Common TSO-DSO AS market model*, the TSO and the DSO have a common objective, meaning that the DSO is willing to provide a level of reactive power, even at the possible cost of additional losses. This is the main difference with the *Local AS market model* where the DSO offers only the amount of reactive power that does not increase/violate the boundaries of losses they want to have.

Similar to previous ancillary services, the processes of prequalification, activation and settlement are relatively similar across coordination schemes. The main differences can be found at the level of procurement as explained before.

5 Assessment of coordination schemes

In this chapter, the benefits and attention points of the different coordination schemes are further analyzed. The impact of the choice of a certain coordination scheme on TSO grid operation, DSO grid operation, other market participants and the functioning of the market are further analyzed.

In addition, it is also assessed how feasible the implementation of a certain coordination scheme is, taking into account the existing regulatory framework, the existing structure of system operators and the ongoing European initiatives in terms of regulation, harmonization and integration.

5.1 Benefits and attention points of coordination schemes

In the next section, the different benefits and attention points of each coordination scheme are further discussed. The analysis focuses on the impact on TSO grid operation, DSO grid operation, other market participants and the market design.

5.1.1 Centralized AS market model

In the *Centralized AS market model*, the DSO is not involved in the procurement of resources from the distribution grid and the TSO has the unique access to all the resources to be used for system services for the entire power system. This coordination scheme is the closest to current practices (see also chapter 3). Due to the low involvement of the DSO, this coordination scheme requires little communication between TSO and DSO in all stages of the processes related to the use of flexibilities (prequalification, procurement, activation and settlement). There is also no need to share data, unless the TSO would include DSO grid constraints automatically in the market clearing. This has the risk of being rather complex, in particular as the TSO has not necessarily the experience or knowledge to understand and interpret the distribution grid data (see section 4.3 for more information related to scenarios). On the other hand, DSOs do not make use of the potential that short-term flexibilities could bring to solve local grid constraints.

There is only one market place which is operated by the TSO. The advantage of one single market operator (who is also the only buyer), is the fact that processes are relatively simple and market products are clear and known to all market participants.

Table 19 gives an overview of the main benefits and attention points related to TSO grid operation, DSO grid operation, other market participants and the functioning of the AS market for the *Centralized AS market model*.

	Benefits	Attention points
TSO grid operation	▪ TSO has access to all resources from distribution grid – no need to share them with the DSO ▪ Few communication between system operators needed	▪ Actions of the TSO might negatively impact the DSO grid and thus grid users connected to the distribution grid
DSO grid operation	▪ Few communication between system operators needed	▪ DSO grid constraints not included ▪ DSOs do not benefit from possible advantages of the use of flexibilities
Other market participants	▪ Easy process and standardized products due to presence of only one central market ▪ Aggregation could use resources from different DSO-areas.	
Market functioning	▪ Coordination scheme close to current markets, so implementation is straight forward ▪ One central market can function at low operational costs ▪ Low operational costs in case DSO grid constraints are not considered	▪ In case DSO grid constraints are considered, need for process of data sharing between TSO and DSO that might outweigh potential benefits

Table 19 stakeholder perspective of Centralized AS market model

5.1.2 Local AS market model

The *Local AS market model* is characterized by the operation of local markets by the DSO. This could result in a very efficient market operation in case of relative large DSOs even though the operation of a local market will result in additional costs for the DSO, compared to a situation where the TSO is responsible for the operation of the market for both resources connected at transmission and distribution level. In case of multiple small distribution grids having each their own local market, this might result in relative or even very illiquid markets and a substantial increase in operational costs (no economies-of-scale-effect and low liquidity result in high prices for flexibility and high costs for market operation, possibly even local market power). In this situation, it should be considered if an additional layer of aggregation could be optimal, this is in particular relevant in case the DSO is not connected directly to the TSO but to another DSO. Also, a shared platform could help in reducing operational costs. In addition, as the local DSO market might be smaller compared to the general TSO AS market, the cost for the DSO for procuring flexibilities might be higher. In the worst case, the DSO cannot contract a sufficient amount of flexibilities and should take unwanted measures such as curtailment or load shedding. The smaller the size of the distribution grid, the higher this risk. The presence of many local markets could also increase the costs for setting up the appropriate communication and ICT infrastructure.

The DSO acts as an aggregator and transfers bids in a smart way to the TSO. The DSO can act as a middleman between aggregators and the TSO. The bids submitted to the DSO could have a different structure compared to the aggregated bids sent to the TSO which could respond more to the TSO requirements, in case they would differ from the requirements of the DSO. Nevertheless, due to the fragmentation of markets, the price for the aggregated bids might be less optimal as bids are determined for each individual DSO-area, eliminating possible combinations of flexible resources, belonging to different DSO-areas. In addition, there might need to be clear rules to guarantee that the different local markets aggregate the bids in a harmonized way. The risk of having multiple local markets lays in the fact that different market products could exist. This is also a barrier to the development of the activity of aggregation by CMPs. However, the existence of different local market products could be an advantage for a particular DSO as the product would be tailor-made to the needs of that particular DSO.

The DSO will activate flexibility resources in order to solve local constraints. This might generate imbalances. The DSO will need to communicate these activations to the TSO, so the TSO is able to correct the perimeters of the BRP and potentially, make corrective actions to restore the balance in the grid.

Table 20 gives an overview of the main benefits and attention points related to TSO grid operation, DSO grid operation, other market participants and the functioning of the AS market for the *Local AS market model*.

	Benefits	Attention points
TSO grid operation	▪ TSO receives aggregated bids that all respect local grid constraints	▪ Price of aggregated bids might be higher due to the fact that aggregation happens only within the individual DSO-area ▪ Priority for the DSO for certain resources, might increase the cost for the TSO who should use more expensive resources ▪ Activations of DSO might create additional imbalances
DSO grid operation	▪ DSO grid constraints included ▪ DSO has priority to use resources from the distribution grid	▪ DSO needs to aggregate local bids into a format requested by the TSO ▪ Operational costs linked with the role of market operator ▪ DSO need to communicate activations to the TSO
Other market participants	▪ Smaller markets might create better conditions for smaller scaled DER	▪ Less possibilities to aggregate several resources into one common bid due to fragmented markets ▪ No possibility to offer flexibility directly to the TSO ▪ Possibility of having different products in different local markets -> need for harmonization
Market functioning	▪ Easy organization of the local market in case of limited number of market participants	▪ In case multiple small distribution grids have their own separate local markets, there could be the risk of fairly illiquid markets with high operational costs ▪ Need for extensive

	communication and ICT infrastructure to implement the communication between (multiple) local markets and the central market ▪ Not in line with current tendencies of harmonization and integration of markets at EU-level

Table 20 stakeholder perspective of local AS market model

5.1.3 Shared balancing responsibility model

The *Shared balancing responsibility model* transfers the balancing responsibility for the DSO-area from the TSO to the DSO, according to a pre-defined schedule. As discussed in section 4.1.3, there are two possibilities to determine this pre-defined schedule:

- The first method uses only nominations of BRPs, taking the outcome of the energy-only market as basis for the schedule. The advantages of this method are the following: it is easy to calculate, the data can be processed quickly and it requires few interactions between TSO and DSO. However, this schedule cannot be determined at the level of the TSO-DSO interconnection point and does not take into account real-time or near to real-time TSO or DSO grid constraints.
- The second method, based on historical forecasts at the TSO-DSO interconnection point, does take into account both BRP nominations and historic and real-time grid constraints. However, this method requires close cooperation between system operators, including sharing of data, and might be time consuming. This is, especially in the case with multiple small DSOs, ambitious with respect to timing.

The amount of AS to be procured by the TSO will be lower in this scheme, due to the fact that a part of the responsibility is transferred to the DSO. In contrast, DSOs will need to procure higher amounts of flexibilities as this flexibility should be used both for balancing and congestion management. In addition, as the local DSO market might be smaller compared to the general TSO AS market, the cost for the DSO for procuring flexibilities might be higher, especially in regions with relative low DRES penetration or few flexible loads. In the worst case, the DSO cannot contract a sufficient amount of flexibilities and should take unwanted measures such as curtailment or load shedding. The smaller the distribution grid, the higher this risk. Also for the grid users, this might result in increased costs as in total, a higher amount of

AS will be procured due to the fragmentation of markets. In conclusion, although TSO costs might decrease, DSO costs will increase relatively more, resulting in higher grid costs potentially billed to the end consumer. In addition, the DSO will need to set up its own system for determining imbalance penalties.

Table 21 summarizes the main benefits and attention points related to TSO grid operation, DSO grid operation, other market participants and the functioning of the AS market.

	Benefits	Attention points
TSO grid operation	▪ Lower amount of AS to be procured, resulting in lower costs for the TSO	▪ TSO has no access to resources connected at the distribution grid for AS purposes ▪ Risk of impact on system stability in case DSO is not able to fulfill its balancing responsibilities
DSO grid operation	▪ DSO grid constraints included	▪ Operational costs linked with the role of market operator ▪ In case multiple small distribution grids have their own separate local markets, there could be the risk of fairly illiquid markets with high operational costs ▪ Amount of flexibility to be procured by DSOs will increase ▪ Cost of procurement might be much higher for the DSO compared to the TSO due to the smaller size of the market ▪ DSO-system for determination and settlement of imbalance penalties is separated from the TSO-system

Other market participants	▪ Smaller markets might create better conditions for smaller scaled DER	▪ Risk of curtailment and load shedding in case of small local markets that generate insufficient resources ▪ Less possibilities to aggregate several resources into one common bid due to fragmented markets ▪ Possible high costs for balancing resources to be paid by grid users and/or BRPs, due to the higher amount of AS to be procured and the higher price of the AS ▪ No possibility to offer resources from the distribution grid to the TSO
Market functioning		▪ Definition of profiled schedule might be complex and time consuming

Table 21 Stakeholder perspective of the sharing balancing responsibility model

5.1.4 Common TSO-DSO AS market model

The main characteristic of the *Common TSO-DSO AS market model* is the common cost optimization where TSOs and DSOs look for a combined solution that satisfies the needs and minimizes the cost. This has as main advantage that grid costs are optimized. It also implies that the DSO has not necessarily priority to use resources from the distribution grid first. Important will be to define how costs are allocated to each individual TSO and DSO. In addition, this coordination scheme could be a basis for further collaboration and/or integration between system operators in case this is efficient from a cost perspective.

Dependent on the chosen variant, the market might be organized as a common market (centralized variant - CV) or as a set of local markets (decentralized variant - DV). The centralized variant could be seen as an extension of the *Centralized AS market model* and the decentralized variant could be seen as an extension of the *Local AS market model*. This means that, for the centralized variant, compared to the *Centralized AS market model*, the TSO has now the advantage to share operational costs with the DSO, but will also need to share resources with the DSO. In the centralized variant, the TSO and the DSO share a

joint responsibility for the operation of the market. In case responsibility is shared between actors to allow for efficient whole system outcomes, a clear framework and processes should be in place to manage interactions. This could for example be achieved by appointing a neutral third party to operate the common market, under supervision of TSOs and DSOs [14].

In the decentralized variant, the DSO is the operator of a local market which might result in additional costs due to market operation, which could be higher compared to a situation where the market is organized as one common market between TSO and DSO. In the common market, operational costs will be lower. In addition, standardization can be expected to be easier and communication requirements might be lower. However, there is a need for both TSO and DSO to share data with the common platform, which requires clear rules for security and privacy of data.

Table 22 summarizes the main benefits and attention points related to TSO grid operation, DSO grid operation, other market participants and the functioning of the AS market.

	Benefits	Attention points
TSO grid operation	▪ TSO could share the costs of market operation with the DSO (CV) ▪ DSO has no priority use any more over local resources (DV)	▪ TSO will need to share resources with DSO (CV) ▪ TSO and DSO will need to share data with common market (CV)
DSO grid operation	▪ DSO grid constraints included (CV&DV) ▪ Low operational costs due to the common operation of the TSO-DSO market (CV)	▪ Operational costs linked with the role of market operator (DV) ▪ In case multiple small distribution grids have their own separate local markets, there could be the risk of fairly illiquid markets with high operational costs (DV) ▪ No priority for the DSO any more to use resources from the distribution grid first (CV&DV) ▪ Less possibilities to aggregate several resources into one common bid due to fragmented markets (DV) ▪ TSO and DSO will need to share

		data with common market (CV)
Other market participants	▪ Grid costs are minimized by minimizing the cost for TSO and DSO in a common optimization process (CV&DV) ▪ Structure of bids to be submitted to the local market might be less complex compared to bids offered directly to the TSO (DV) ▪ Smaller markets might create better conditions for smaller scaled DER (DV) ▪ Easy process and standardized products due to presence of only one central market (CV) ▪ Aggregation could use resources from different DSO-areas (CV)	▪ Less possibilities to aggregate several resources into one common bid due to fragmented markets (DV)
Market functioning		▪ Need for extensive communication and ICT infrastructure to implement the communication between (multiple) local markets and the central market (DV)

Table 22 Stakeholder perspective of common TSO-DSO AS market model

5.1.5 Integrated flexibility market model

The main characteristics of the *Integrated flexibility market model* are the introduction of non-regulated market players as buyers in this market model. In addition, this market set-up requires the presence of a new entity, the independent market operator to guarantee neutrality towards all market participants. The flexibility is allocated to the market party with the highest willingness to pay. This creates already a first attention point as in this scheme, it might be possible that market parties compete

for the same resources, increasing the price or alternatively, TSO and DSO might each activate flexibilities that negatively influence each other's positions. This could even lead to unnecessary high costs of grid operation, which in the end are carried by the grid user.

The introduction of non-regulated market parties might increase the liquidity of the market. Depending on their risk management strategies, CMPs might require lower volumes bought in day-ahead and intraday as they have the possibility in real-time or near-to-real-time to buy or sell additional volumes to correct their positions. In addition, both TSOs and DSOs are allowed to resell previously contracted flexibility back to the market. This is supporting the liquidity as well. Nevertheless, clear rules should be defined about the price at which system operators can resell previously contracted volumes in order not to stimulate any gambling behavior. A possible rule could for example be to resell all volumes at the previously contracted price.

The fact that there is one common market place for all flexibility providers and customers might also increase the participation of DER and facilitate the operational process for aggregators as there is only one common market platform. Not only the sellers of flexibility have an interest, but also BRPs that are buyers of flexibility might have the possibility to lower imbalance penalties as they can correct their position closer to real-time. Nevertheless, the presence of both regulated and non-regulated parties in one common market might raise some specific concerns. First, it will be difficult for the TSO to determine the amount of AS to be procured as the CMPs can also buy flexibility almost in real-time to keep their positions balanced. This will of course be mainly an issue at the start of the integrated market. If several market sessions have taken place, the TSO has a good view on the volumes typically needed. In addition, the TSO might still procure reserves outside the common market which could be used as an additional security measure. However, AS procurement of the TSO outside the market, might impact the liquidity of the market itself and could be a barrier for the development of the integrated market. In addition, a smart balancing settlement mechanism could be installed, giving CMPs the right incentives to procure the 'by the TSO desired amounts' in the flexibility market. Another concern might be that opening the AS markets for CMPs, might hinder further development of intraday markets. See further discussion on this topic in section 5.2.3.

The presence of an additional entity, i.e. the IMO, has the benefit that the market will be operated by an entity that might already have experience in this field. The IMO could be for example an entity that is already today responsible for the operation of day-ahead and intraday markets. In addition, the presence of an IMO might guarantee neutrality which is essential for market players. The IMO could for example be involved in the process of prequalification or blocking of bids (see section 4.3 for a detailed discussion), to avoid any conflict of interest for the DSO in his role as seller and in his role as flexibility feasibility checker. However, it might require a clear framework where responsibilities of the IMO towards both system operators and non-regulated market parties are clarified. In addition, the operation of this market,

in particular the integration of grid constraints, requires the sharing of data by system operators with this independent entity. This is only possible in case clear rules for data security and privacy are determined.

Table 23 summarizes the main benefits and attention points related to TSO grid operation, DSO grid operation, other market participants and the functioning of the AS market.

	Benefits	Attention points
TSO grid operation	▪ General lower need for resources as BRPs have increased possibilities to balance their portfolios ▪ Lower cost due to high liquidity ▪ Possibility to resell unneeded resources bought upfront ▪ Access to unneeded previously contracted resources from the DSO	▪ Risk of procuring more resources than needed ▪ Need for sharing of data with IMO ▪ TSOs and DSOs might compete for the same product, increasing total cost ▪ TSOs and DSOs might activate opposing flexibilities
DSO grid operation	▪ DSO grid constraints included ▪ Lower cost due to high liquidity ▪ Possibility to resell unneeded resources bought upfront ▪ Access to unneeded previously contracted resources from the TSO	▪ Need for sharing of data with IMO ▪ In case the IMO is not responsible for prequalification and blocking of bids, potential conflict of interest ▪ No priority for the DSO to use resources from the distribution grid first ▪ TSOs and DSOs might compete for the same product, increasing total cost ▪ TSOs and DSOs might activate opposing flexibilities
Other market participants	▪ Common market place for all flexibility providers might facilitate operational process ▪ Lower imbalance penalties due to access to flexibility close to	▪ Liquidity of intraday market might decrease

	real-time ▪ Facilitates the participation of DER to the market ▪ Aggregation could use resources from different DSO-areas.	
Market functioning	▪ Participation of non-regulated parties might increase liquidity ▪ One common platform for all market participants ▪ Operational costs of market operation lower for individual party as they can be shared by a large number of participants	▪ Additional market player to be introduced where clear definition of responsibilities is needed ▪ Potential negative impact on the development of Intraday markets

Table 23 Stakeholder perspective of the integrated flexibility market model

5.1.6 Summary of benefits and attention points of different coordination schemes

Table 24 summarizes benefits and attention points of the coordination schemes.

Coordination Scheme	Benefits	Attention points
Centralized AS market model	▪ Efficient scheme in case only the TSO is a buyer for the service ▪ A single market is low in operational costs and supports standardized processes ▪ Most in line with current regulatory framework	▪ No real involvement of DSO ▪ DSO grid constraints not always respected
Local AS market model	▪ DSO has priority to use local flexibility ▪ DSO supports actively AS procurement ▪ Local markets might create lower entry barriers for small scaled DER	▪ TSO and DSO market cleared sequentially ▪ Local markets might be rather illiquid ▪ Need for extensive communication between the TSO market and the local DSO markets
Shared balancing responsibility model	▪ The TSO will need to procure a lower amount of AS ▪ Local markets might create lower entry barriers for small	▪ Total amount of AS to be procured by TSO and DSO will be higher in this scheme

	scaled DER ▪ Clear boundaries between system operation TSO and DSO	▪ BRPs might face higher costs for balancing ▪ Small local markets might be not liquid enough to provide sufficient resources for the DSO ▪ Defining a pre-defined schedule methodology agreed by both TSO/DSO might be challenging
Common TSO-DSO AS market model	▪ Total system costs of AS for the TSO and local services for the DSO are minimized ▪ TSO and DSO collaborate closely, making optimal use of the available flexible resources	▪ Individual cost of TSO and DSO might be higher compared to other schemes ▪ Allocation of costs between TSO and DSO could be difficult
Integrated flexibility market model	▪ Increased possibilities for BRPs to solve imbalances in their portfolio ▪ High liquidity and competitive prices due to large number of buyers and sellers	▪ Independent market operator needed to operate the market platform ▪ Negative impact on the development and liquidity of intraday markets ▪ TSO and DSO need to share data with IMO

Table 24 benefits and attention points of coordination schemes

5.2 Feasibility of coordination schemes

The feasibility of a certain coordination scheme depends on the regulatory framework, the organization of DSOs and the ongoing initiatives for harmonization and integration of AS markets. The literature review in chapter 3 illustrated the ongoing discussions on the European regulatory framework and the impact on TSO-DSO cooperation. In this section, the main elements are highlighted that are a precondition for a certain coordination scheme to be able to be implemented.

5.2.1 Regulatory framework

The main precondition for each of the coordination schemes is the fact that DER are allowed to participate to AS markets. Although this seems to be trivial, the country survey in chapter 3 illustrated that in some countries, i.e. Italy, DER are not yet allowed to participate to AS markets. Hence, some new

market players, i.e. aggregators, are not recognized in some countries or different rules apply dependent on the country.

In addition, the evolution of the roles and responsibilities of system operators will determine the feasibility of a certain coordination scheme. Today, the TSO has the sole responsibility to balance the system. In the *Shared balancing responsibility model*, this responsibility is partially transferred to the DSO.

Except for the *Centralized AS market model*, all coordination schemes assume that the DSO contracts flexibility resources to solve local grid constraints. Today, this is not done by DSOs due to issues related to the regulated cost structure of DSOs (flexibility procurement not necessarily considered as operational expense and not refunded). Therefore, it is important that the procurement of flexibility resources will be recognized as operational expense. In addition, for the *Common TSO-DSO AS market model*, the key characteristic is the common optimization. This is only feasible in case the rules for the cost recognition of flexibilities are aligned between TSOs and DSOs and if the regulatory framework determines a common objective to minimize total expenses for TSOs and DSOs. This also implies clear guidelines on how to make a correct trade-off between investments in infrastructure, the use of flexibility resources and the use of e.g. non-firm grid access contracts.

In the *Local AS market model* and the *Common TSO-DSO market model* (decentralized variant), the DSO acts as an aggregator on behalf of the TSO. This is also a specific role that needs clarification in regulation.

Besides roles and responsibilities, the DSO grid constraints and the way to respect them is today not enforced by law. This means that processes for system prequalification or active blocking of bids are rarely installed.

Table 25 summarizes the main regulatory barriers that might hinder the implementation of a specific Coordination Scheme.

Coordination Scheme	Regulatory barriers
Centralized AS market model	▪ No process for prequalification or active blocking of bids by DSOs enforced by law
Local AS market model	▪ No cost remuneration for DSOs who contract flexibilities ▪ DSOs not allowed to be an aggregator on behalf of the TSO
Shared balancing responsibility model	▪ Today, the TSO is the only entity responsible for the entire balancing of the system ▪ No cost remuneration for DSOs who contract flexibilities
Common TSO-DSO AS market model	▪ No common cost objective for TSOs and DSOs ▪ No cost remuneration for DSOs who contract flexibilities ▪ DSOs not allowed to be an aggregator on behalf of the TSO

Integrated flexibility market model	▪ No cost remuneration for DSOs who contract flexibilities ▪ Today, commercial market parties are not allowed to participate in AS markets ▪ TSOs and DSOs should be allowed to resell previously contracted flexibility to the market ▪ No process for prequalification or active blocking of bids by DSOs enforced by law

Table 25 Regulatory barriers for coordination schemes

In conclusion, the *Centralized AS market model* has the least obstacles for implementation from a regulatory point of view. This coordination scheme differs the least from current organization of AS markets and it is the only coordination scheme which is today already applicable for a selection of AS in some countries. See also the country review in chapter 3 for more details on the current applicable coordination schemes in the surveyed countries. The other coordination schemes will require substantial changes in roles and responsibilities for system operators and commercial market parties in case the implementation of one of these coordination schemes is envisioned.

5.2.2 Organization of distribution system operators

The coordination schemes as discussed in chapter 4 are focusing on the interaction between TSO and DSO, without explicitly considering the way DSOs are organized on a national level. In some countries, i.e. Norway or Germany, there are a lot of relatively small DSOs. The question arises how feasible the different coordination schemes are in case the number of DSOs is high. The type and nature of DSOs (e.g. size, DSO-connected or TSO-connected) should be taken into account when designing the instruments and requirements to deliver the wider objectives, in order to avoid disproportionate or negative cost/benefit impacts [14].

In the *Centralized AS market model*, the DSO is not involved in the process of procurement or activation. Dependent on the way local grid constraints are handled (see section 4.3), the DSO could be involved in a process of prequalification or manual or automated blocking of activations. In case multiple DSOs should communicate with one single TSO, it is obvious that this can only be an automated system. In case a system of manual blocking of activations is chosen, the operational costs might be much higher compared to the benefits. In addition, it might not be feasible to organize this manual check by multiple DSOs within the limited time frame, i.e. the iterative process of multiple clearings has to happen within a dedicated time frame in order to be able to communicate the results to all market players.

In the *Local AS market model*, the *Shared balancing responsibility model,* the *Common TSO-DSO AS market (decentralized variant)*, DSOs are each responsible for the organization of a local market. In case

the respective distribution grid is too small, this might result in very illiquid markets. In addition, for the *Shared balancing responsibility model*, in case the DSO has to comply with a scheduled profile for its individual DSO-area, the costs of balancing might be much higher due to the illiquidity of the market and the fact that the portfolio effect is much lower (lower probability of opposite deviations that cancel each other out). In order to avoid that a large number of small illiquid markets are created, at a high cost and high operational burden, there is need for coordination between DSOs. This could for example by aggregating several smaller DSO-areas into one common DSO-area. The organization of this aggregated DSO market could be done by the DSOs itself or could be outsourced to an independent actor to increase the efficiency of the process and to guarantee neutrality. The coordination schemes will then define the interaction between the TSO and the aggregated DSO-area.

For the *Common TSO-DSO AS market (centralized variant)* and the *Integrated flexibility market model*, the impact of the number of DSOs is limited as the coordination scheme aggregates already the entire TSO and DSO area of flexibilities. For the *Integrated flexibility market model*, the same remark is valid as for the *Centralized AS market model*, i.e. the integration of DSO grid constraints should be organized in an automated way to ease the operational process. Also, for very small DSOs, it might be time consuming to participate to the market themselves and it could be a possibility that the responsibility for market participation is assigned to one larger DSO, or an independent body, representing several smaller DSOs.

5.2.3 European evolution towards harmonization and integration

Several initiatives are ongoing in Europe to promote further harmonization and integration of the EUs internal energy market. The market coupling of day-ahead markets is close to being finalized and the coupling of intraday markets is ongoing. This evolution of the intraday market is in particular relevant for the *Integrated flexibility market model*. In principle, both the intraday market and the *Integrated flexibility market model* could co-exist as long as they complement each other. That is, different services are offered in each market. However, in case the same services are traded in both markets, it is more efficient to integrate both markets while extending the scope of current intraday markets, i.e. allowing for trades closer to real-time.

In addition, several initiatives are taken to harmonize AS markets. There is for example a common cross-border weekly auction market for FCR between Germany, Austria, The Netherlands, Belgium and Switzerland. It is expected that also Denmark and France will join this common auction in the near future [33]. Also the markets for AS are subject to further integration. The Network Code on Electricity Balancing determines further requirements for the harmonization of balancing markets, the effective cross-border sharing of balancing resources and the netting of imbalances [22]. This also means further cross-border integration for aFRR, mFRR and RR [34].

The emphasis on cross-border integration and harmonization of national markets is important in the context of the coordination schemes between TSO and DSO. The coordination schemes determine the possible interactions between TSO and DSOs on a national level. As explained before, dependent on the local situations or the type of product, certain coordination schemes might be more appropriate compared to others. This could result in differences between countries. However, with regards to the future DSO and TSO relationship, CEER believes that general principles should be defined on European level, while more detailed regulation, for the implementation of common principles in the respective countries, should be developed at a national level [14] .

Of course, it is always possible that, in addition to a common European market for AS, each country has a national (or regional) AS market, especially for resources connected at the distribution grid. This is a reasonable option, especially in countries where the participation of DRES from the distribution grid to AS markets is still limited. In this case, there is no conflict between a specific national market and the evolution towards common markets for AS procurement.

However, the question arises if in a situation with large shares of DER participating to AS markets, it is still efficient to have a common market on the one hand and a local market on the other hand. It is obvious that having the co-existence of two markets is not cost-efficient and might limit the support DRES could give, i.e. in some countries, the share of DRES is large and could also give cross-border support. The problem is mainly relevant for FRR and RR products. As discussed in section 4.5.4, voltage control is a very local issue from a TSO (and DSO) perspective and it seems reasonable to assume that for this AS product, the market will be organized at a national or even more local level. For FCR, the *Centralized AS market model* and the *Common TSO-DSO AS market model* (centralized variant) were proposed as main coordination schemes. As the latter could be seen as a more advanced version of the former, both coordination schemes are compatible and do not hinder further cross-border harmonization or integration.

For AS products used for balancing and congestion management, all coordination schemes are in principle possible. It is in this case that most attention should be given how these national markets in the future will be harmonized naturally, especially as the more markets are integrated, the lower the amount of AS to be procured will be. Of course, a choice for a certain coordination scheme is not final and changes in roles and responsibilities (e.g. enforced by new EU regulation, see also 5.2.1) could move countries into the direction of a certain coordination scheme. Nevertheless, the main message is that, before extensive investments are made in communication and ICT infrastructure to organize a national market, discussions on European level should take place how these national developments do not hinder further European integration. Although the diversity of national arrangements (e.g. voltage levels for electricity or pressure levels for gas, roles and responsibilities, capabilities, interests, etc.) may preclude the development of one-size-fits-all solutions, NRAs, DSOs and TSOs across European countries should

cooperate to agree common approaches, where these better facilitate the optimal operation of the system, i.e. in a secure, sustainable and cost-efficient manner [14].

5.2.4 Feasibility of coordination schemes: feedback from the consultation

In terms of feasibility of the coordination schemes, respondents are relatively in line in the consultation (annex 8.2). The *Centralized AS market model* is considered as most compatible with existing AS markets and as a result, will be feasible already today or in the near future. Other coordination schemes seem to be considered as feasible by 2030, however, clear preferences exist for specific schemes.

Although the *Centralized AS market model* is closest to current market organization, it is only put forward as the preferred scheme by a limited number of respondents. Most respondents consider this scheme as sufficient for the kick-start of the market but too constrained in terms of dynamic interaction of TSOs, DSOs and commercial market players. Also, this scheme does not address the DSO needs sufficiently.

Most respondents do not favor the *Local AS market model* or the *Shared balancing responsibility model* as they are both considered as not very cost-efficient, lacking economies of scale. Therefore, although considered as feasible by 2030, it is by none of the respondents the preferred option.

Almost all respondents have a clear preference for the *Common TSO-DSO AS market model* or the *Integrated flexibility market model*. Both market models seem to provide the most coherent answer to future grid, system and market challenges.

Respondents with a preference for the *Common TSO-DSO AS market model* emphasize as most important advantages the common optimization of the use and the cost of flexibility by system operators. Respondents with a preference for the *Integrated flexibility market* highlight the fact that the more buyers you allow in a market, the higher the liquidity and the lower the costs will be. This market might also give incentives to investors which areas in the grid could benefit from investments in flexibility.

In terms of barriers, respondents are in line, highlighting several relevant issues.

A general precondition for the feasibility of the coordination schemes is the development of flexibility from the distribution grid. In addition, the access by DER to different markets is key. This also implies that all (regulatory) barriers to aggregation should be removed.

Another important barrier, emphasized by most respondents is the evolution of the role of the DSO. DSOs should be allowed to contract flexibility in a cost-efficient way. This also means that DSOs should develop the necessary business models and tools to anticipate to the use of flexibility, i.e. for grid planning, operational planning and real-time monitoring and control.

In addition, mentioned by several respondents, the incentive regulation for both TSOs and DSOs should take into account the use of flexibility and should develop specific performance targets that are in line with the participation to the upcoming flexibility markets.

Two respondents underline the current status of unbundling as a potential barrier. For example, there might be the risk that, in case DSOs are not unbundled, vertically integrated companies are favored as flexibility provider by the DSO. The rules for unbundling also limit the trading possibilities of flexibility for DSOs.

Two respondents mention the existence of multiple TSOs and DSOs in one country that might hinder the implementation of certain coordination schemes. Specific attention should be given to solutions to facilitate TSO-DSO coordination in case multiple TSOs and DSOs are concerned.

One respondent emphasizes the need for new ways of data handling as, due to the increased real-time interaction between system operators and market parties, more data need to be processed/shared within a short time frame.

6 Conclusions and key messages

The increase of DER, mainly connected at the distribution grid, provides opportunities for system operators to make use of flexibility from the distribution grid. Different mechanisms for coordination between TSO and DSO have been examined in the context of this report. The main key messages are listed below.

1. The choice of the appropriate coordination scheme is dependent on multiple factors such as the type of ancillary service, normal operation versus emergency situations, the state of the grid, the amount of RES installed, the current market design and the regulatory framework.

2. TSO-DSO coordination could be organized on a country level, but we should strive to integrate national TSO-DSO coordination set-ups within the process of EU harmonization and integration. This means that processes and systems should be made dynamically to anticipate on future harmonization and integration.

3. The feasibility of coordination schemes is very dependent on the evolution of roles and responsibilities of the DSO and vice versa.

4. A trade-off should be made between the benefits of a certain coordination scheme and the cost of implementing this scheme. For example, it might be very costly to install a system of full observability where all DSO constraints are monitored in real-time in case constraints are almost never violated.

5. The choice for a specific coordination scheme does not imply that this scheme could never be adapted. Across coordination schemes, there is a gradual increase of the role and responsibilities of the DSO. Dependent on the national evolution, a country can evolve from one coordination scheme to another. In particular, the *Centralized AS market model*, the *Common TSO-DSO AS market model* (centralized variant) and the *Integrated flexibility market model* share a common market architecture in terms of market platform and ICT requirements. A shift between these coordination schemes is mainly a question of a change in roles and responsibilities. The *Shared balancing responsibility model* could be seen as a duplication of the same market architecture as well. Also the *Local AS market model* and the *Common TSO-DSO AS market model* (decentralized variant) share a common market architecture.

6. Independent of the coordination scheme, the procurement of AS from the distribution grid should be clear, easy to understand, reliable, cost-efficient and fast. In case interaction models are too complex, the value for smaller flexibility providers of DER might be heavily reduced.

7. Independent of the coordination scheme, the procurement of AS from the distribution grid, should be *transparent*, *non-discriminatory* and *neutral*. This is in particular relevant for small DSOs, procuring flexibility, in case they are vertically integrated with a non-regulated energy player.

8. A closer cooperation between TSOs and DSOs will still require that system operators remain responsible for the operation of their grid and the management of their data in a secure way.

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8 Appendices

8.1 Appendix 1: Overview DER participation to AS markets

	AS product	Product name	Procurement mechanism	Type of DER
AT	FCR	Primary Control	Tender	Hydro
	aFRR	Secondary Control	Tender	Demand response, industrial generation, emergency generators, storage, etc.
	mFRR	Tertiary Control	Tender	Demand response, industrial generation, emergency generators, storage, etc.
BE	FCR	Primary frequency control (R1-Down and R1–Load (Up))	Tender	Flexible generation and load
	mFRR	Tertiary reserve (R3-DP)	Tender (Yearly and monthly)	DR (Interruptible or downward controllable demand)
DK	FCR	Primary Control	Daily auction (DK1/DK2)	CHPs, electric boilers, battery
	aFRR	Secondary Reserve (DK1)	Daily tender (DK2) Bilateral (DK1)	CHPs, electric boilers
	mFRR	Tertiary (Manual) Reserve (DK1 and DK2)	5 year tender (DK2) Daily auction (DK1)	CHPs, electric boilers
ES	FCR	Frequency containment reserve	Mandatory	All of them (upon approval from TSO) (since December 2015)
	FRR	Frequency restoration reserve	Market	All of them (upon approval from TSO) (since December 2015)
	RR	Replacement reserve	Market/Mandatory	All of them (upon approval from TSO) (since December 2015)
	Other	Deviation	Market	All of them (upon approval from TSO)

		management		(since December 2015)
	Other	Power factor control	Mandatory	All of them
FI	FCR	Frequency controlled normal operation reserve (FCR-N)	Yearly and Hourly Market/ Bilateral contracts	Medium size industrial and commercial consumers such as a large deep freeze storage pilot, and experimental battery storage systems.
	FCR	Frequency controlled disturbance reserve (FCR-D)	Yearly and Hourly Market/Bilateral contracts	Medium size industrial and commercial consumers such as a large deep freeze storage pilot, and an experimental battery storage system.
	mFRR	Fast disturbance reserve (mFRR)	Regulating Power Market/ Bilateral contracts	100 – 300 MW from DR. Type varies depending on the market but typically medium size industrial and commercial loads.
	Other	Peak load reserve	market	10 MW from one heat pump NA
	Other	Heating load reduction for last reserve. (Pilot)	Bilateral contract between DSO and TSO. (pilot)	About 20 MW aggregated from residential houses.
NO	mFRR	Fast disturbance reserve (mFRR)	Daily tender, plus additional seasonal market	No limitations as long at the activation requirements are met.

Table 26 Overview of DER participation to AS markets

8.2 Appendix 2: Questions consultation

Role of the TSO and the DSO:

1. Should the TSO be responsible for solving both congestion at transmission and distribution level?

2. Should the DSO become the market operator of a local market for flexibilities or should this be organized by an independent market operator?

3. Would it be a possibility that the DSO becomes responsible for the balancing of the distribution grid during normal day-to- day operation? What would be benefits or risks?

4. Is it realistic to assume that DSOs will also buy local flexibility in real-time or near to real-time to solve local congestion, compared to network reinforcements or buying flexibilities in long term?

5. What could be other out-of- the box options to increase efficiency of TSO-DSO coordination which have not been discussed in this consultation document? What would be advantages or disadvantages of your suggestion?

Market design:

6. Is it from a market design point of view, optimal, to organize local markets for flexibility at the level of the individual DSO? Could groups of small DSOs be pooled together?

7. What is your opinion on a common market for both TSOs and DSOs to buy flexibility for their own purposes?

8. Should commercial market parties (balance responsible parties) have access to the same flexibility market as TSOs and DSOs to buy resources to balance their portfolio?

9. In case both TSOs and DSOs contract flexibility from the Distribution grid in real-time or near to real-time:

a. Should there be priority for the TSO?

b. Should there be priority for the DSO?

c. Should the total costs for both TSO and DSO together be optimized, without allocating upfront priority for one of the two network operators?

10. Should the common market for TSOs and DSOs be operated by the TSO, by the DSO, by the TSO and DSO together or by an independent market operator?

11. Which of the coordination schemes would facilitate the participation of local flexibility to the market the most, the least?

Use cases:

12. How do you assess the relevancy of the proposed use cases with respect to the increased need for TSO-DSO interaction. Which of the use cases is the most important and why?

13. Are there additional use cases, not proposed, that should be investigated in the context of ancillary service provision by TSOs and local service provision by DSOs?

Feasibility of the coordination schemes:

14. How do you estimate the feasibility of the 5 coordination schemes (feasible today, feasible by 2030, feasible in the long term, not feasible?)

15. What are the relevant barriers, both at national and European level, for the feasibility of the different coordination schemes with respect to:

- The current role of the TSO
- The current role of the DSO
- The current market design
- The current rules and procedures for network operation
- The remuneration for TSOs and DSOs
- European regulation (current and expected)
- Other relevant aspects

16. How do you see the relation between TSOs and DSOs within the process of European integration and harmonization?

8.3 Appendix 3: Overview respondents consultation

Nineteen answers were received for the consultation. Eighteen answers were considered complete and the feedback is integrated in the report.

The answers provided came from 10 different countries. Figure 15 gives an overview of the respondents per country.

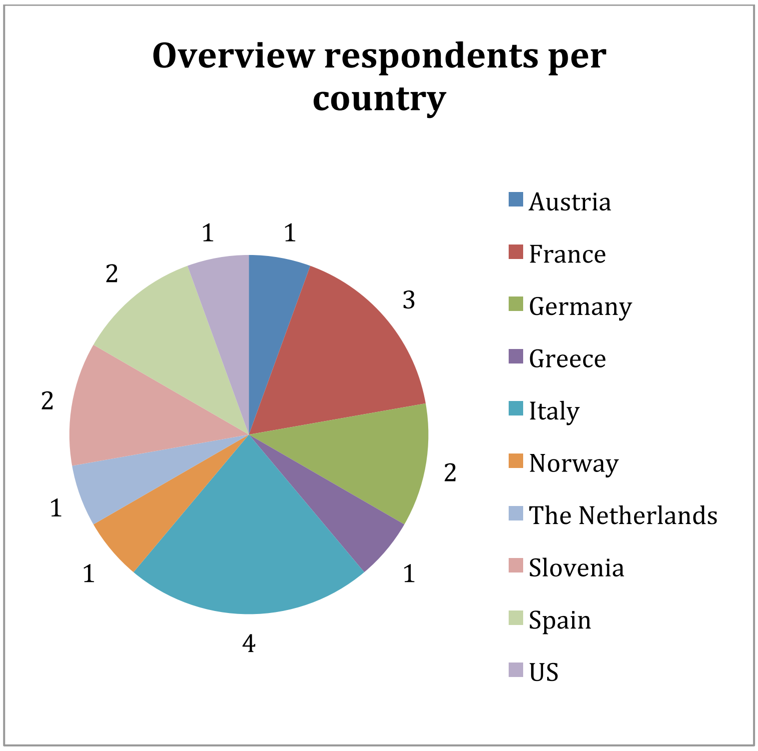

Figure 15 Overview respondents per country

The background of the respondents was diverse, i.e. regulators, system operators, research institutes and commercial companies provided feedback. Figure 16 gives an overview of the respondents per category.

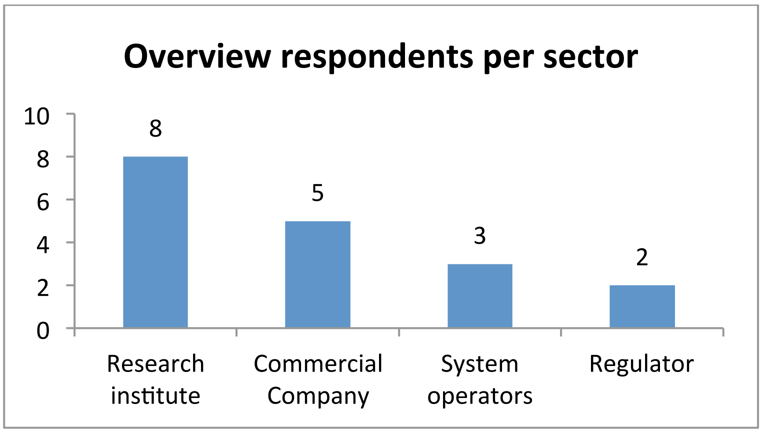

Figure 16 Overview respondents per sector